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Emergency and Clinical Ultrasound

BOARD REVIEW

Alan T. Chiem
Vi Am Dinh

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EMERGENCY AND CLINICAL ULTRASOUND BOARD REVIEW

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EMERGENCY AND CLINICAL ULTRASOUND BOARD REVIEW

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OXFORD
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Published in the United States of America by Oxford University Press
198 Madison Avenue, New York, NY 10016, United States of America.

Library of Congress Control Number: 2020930969
ISBN 978–0–19–069682–5

1 3 5 7 9 8 6 4 2

Printed by Integrated Books International, United States of America

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ACKNOWLEDGMENTS

We ostensibly developed this book to help clinicians to prepare for the ABEM Advanced Emergency Ultrasound and NBE Critical Care Echocardiography Board Exams. However, as we started our work three years ago, we began to realize the potential of point-of-care ultrasonography (POCUS) to be a unifying force in medicine. More and more specialties and healthcare professions are training in POCUS, in order to more accurately, safely, and cost-effectively manage their patients. To reflect this evolution, we recruited a multi-specialty team of over 50 POCUS experts to contribute to this work. We hope that our work will help to lay the foundation for point-of-care ultrasound for all practitioners of medicine. Our ultimate hope is that by helping to bring POCUS to clinicians, they will be able to increasingly, and more meaningfully, bring the practice of medicine back to the bedside.

Without my wife, Bonnie, and children, Naomi and Gabriel; as well as my friends and colleagues, this book would not be possible. I would like to also thank our Oxford University Press editors for bringing our work into fruition.

AC

I want to thank my wife, Minh, and two children, Aria and Emmett for their support and patience as this book was completed. I also want to thank the many expert co-authors that spent countless hours to make this happen.

VD

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EMERGENCY AND CLINICAL ULTRASOUND BOARD REVIEW

1.

FOCUSED ASSESSMENT WITH SONOGRAPHY IN TRAUMA (FAST)

Caroline Brandon, Jaime Moran, Dana Sajed, and Tarina Kang

QUESTIONS

1. A 27-year-old male is brought in by emergency medical services (EMS) after sustaining multiple gunshot wounds to the abdomen, flank, and buttock. Initial vitals are heart rate (HR) 117, blood pressure (BP) 89/42, and respiratory rate (RR) 26, with an oxygen (O_2) saturation of 99% on room air (RA). Initial Focused Abdominal Sonography in Trauma (FAST) is shown in Figure 1.1, Video 1.1, Video 1.2, and Video 1.3.

What is the best next step?

A. Send patient for a computed tomography (CT) scan of the abdomen and pelvis.
B. Perform serial hemoglobin checks and FAST exams.
C. Give crystalloid, pain medication, and perform labs.
D. Go to operating room (OR) for an exploratory laparotomy.

2. A 33-year-old male is brought into the emergency department (ED) by EMS after a high speed roll-over multiple vehicle collision. Initial vitals are HR 123, BP 126/50, RR 30, and O_2 saturation of 99% on RA. Initial FAST is shown in Figure 1.2.

What is the best next step?

A. Perform a CT scan of the abdomen and pelvis.
B. Perform serial hemoglobins and FAST exams.
C. Give crystalloid, pain medication, and perform labs.
D. Go to the OR for an exploratory laparotomy.

3. The hepatorenal view of the FAST is considered negative if no free fluid is found at the liver tip, the inferior pole of the kidney, and within:

A. Morison's pouch.
B. The splenorenal space.
C. The Pouch of Douglas.
D. The ureterovesicular space.

4. A 22-year-old woman presents after falling 20 feet off a balcony. Upon arrival to the ED, the patient was in respiratory distress and altered. She had ecchymosis along her chest and abdomen. The initial extended FAST (EFAST) was negative. She was intubated. A repeat postintubation EFAST showed normal lung sliding on the right and a lung pulse on the left. At this point, you:

A. Send the patient to CT scan.
B. Prepare for chest tube placement of the left lung for pneumothorax.
C. Deflate the balloon and pull the endotracheal tube back.
D. Deflate balloon and push endotracheal tube forward.

Figure 1.1 (a) **Right upper quadrant FAST view.** (b) **Left upper quadrant FAST view.** (c) **Suprapubic FAST view.**

Figure 1.2 (a) **Right upper quadrant FAST view.** (b) **Left upper quadrant FAST view.** (c) **Suprapubic FAST view.**

5. A 34-year-old female who presents with abdominal pain after falling down a flight of stairs. Vital signs are stable but she is peritonitic on physical exam. Initial FAST is negative. CT shows free abdominal fluid and a grade 3 splenic laceration. Which of the following best explains why the FAST was negative?

A. The specificity of FAST is low especially if only a small volume of hemoperitoneum is present.
B. The sensitivity of FAST is low especially if only a small volume of hemoperitoneum is present.
C. The specificity of FAST is high especially if only a small volume of hemoperitoneum is present.
D. The sensitivity of FAST is high especially if only a small volume of hemoperitoneum is present.

6. Unlike acute hemorrhage, thrombus, and clots on ultrasound:

A. Are hypoechoic or hyperechoic.
B. Are anechoic.
C. Generate acoustic enhancement artifact.
D. Generate side lobe artifact.

Figure 1.3

7. A 56-year-old male with an unknown past medical history was found lying on the side of the road. He has abrasions on his face, hands, and knees. He smells of alcohol but is now awake and able to answer questions. Vital signs are HR 89, BP 110/78, RR 17, and temperature (T) 98.9. The FAST RUQ window is shown in Figure 1.3 and Video 1.4.

What is the next best step in management?

A. Go to the OR immediately for an exploratory laparotomy.
B. Do nothing. The peritoneal fluid is ascites.
C. Perform a CT scan of the abdomen and pelvis.
D. Initiate the massive transfusion protocol.

8. A 19-year-old female is involved in a high-speed motor vehicle collision. She was restrained. Airbags were deployed, but she hit her head on the dashboard. She is complaining of diffuse abdominal pain and vomited twice in the ED. Vitals are stable. FAST is negative. CT of the abdomen and pelvis is negative for acute traumatic injury. What is the next best step in management?

A. Discharge home with ODT (oral dissolving tablet) Zofran and primary care follow-up.
B. Go to the OR for exploratory laparotomy.
C. Repeat CT scan in 6 hours.
D. Admit for monitoring/serial abdominal exams given the concern for possible delayed bowel injury.

9. A 27-year-old male presents to the ED with stab wounds to the RUQ and epigastrium. Vitals are stable. The patient is diffusely peritonitic on physical exam. Initial FAST is negative, How can the sensitivity be increased to detect fluid on the FAST exam?

A. Place patient in reverse Trendelenburg position.
B. Place patient in Trendelenburg position.
C. Place the patient in left lateral decubitus position.
D. Sit the patient upright.

10. Which probe is recommended when performing the FAST exam?

A. Linear probe
B. Curvilinear probe
C. Phased array probe
D. B and C

11. A 24-year-old male presents with a gunshot wound to the right thorax. EFAST is shown in Figure 1.4 and Video 1.5. What does the ultrasound image depict, and what is it commonly referred to as on ultrasound?

Figure 1.4

A. Pneumothorax, lung point
B. Normal thoracic ultrasound, lung sliding
C. Consolidation, lung pulse
D. Hemothorax, spine sign

12. A 31-year-old male presents after a low-speed motorcycle crash, where the patient skidded 15 feet after laying his bike down. Vitals are HR 110, BP 136/91, and RR 18 with an O_2 saturation of 98% on RA. FAST is performed, but because of pain in the epigastric region, the traditional subxiphoid cardiac images cannot be obtained.

What is the next best step in management?

A. Press harder with a different transducer probe.
B. Obtain a parasternal long axis view of the heart.
C. Obtain a CT scan of the heart.
D. Move on to the rest of the FAST exam.

13. Why is the perisplenic (LUQ) view more difficult to obtain than the hepatorenal (RUQ) view?

A. The spleen provides a smaller acoustic window than the liver.
B. The perisplenic space is more posterior and cephalad than the perihepatic space.
C. The spleen and the perisplenic space are easily obscured by rib shadow.
D. All of the above.

14. A patient presents to the ED with respiratory distress after being stabbed in the chest. A CT scan of the chest shows a pneumothorax with subcutaneous emphysema. The FAST exam is performed, which is shown in Figure 1.5.

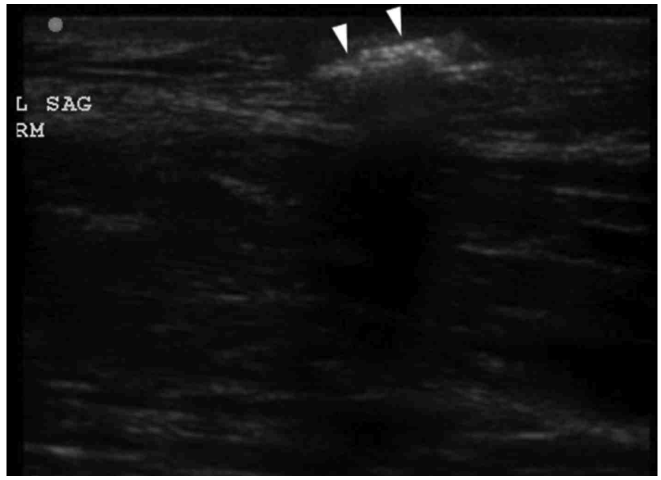

Figure 1.5 **Subcutaneous air on the EFAST exam of the thorax.** From Figure 5A of Buttar S, Cooper D Jr, Olivieri P, et al. Air and its sonographic appearance: understanding the artifacts. *J Emerg Med*. 2017;53(2):241–247.

What is the artifact seen in the image?

A. Side lobe artifact
B. Scatter artifact
C. Edge artifact
D. Twinkle artifact

15. Which of the following windows is not part of the abdominal FAST?

A. Suprapubic window
B. Subxiphoid cardiac window
C. Hepatorenal window
D. Proximal aorta window

16. Which probe is preferred to evaluate the lungs for pneumothorax and why?

A. Linear probe, because it is a high-frequency probe
B. Phase array, because it is a high-frequency probe
C. Phase array, because it is a low-frequency probe
D. Curvilinear, because it is a high-frequency probe

17. A 57-year-old man presents with chest pain after being hit in the chest with a baseball bat. You perform the thoracic portion of the EFAST, shown in Figure 1.6 and Video 1.6.

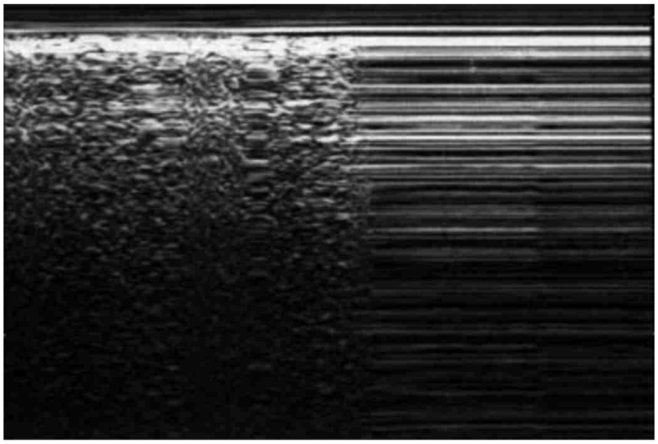

Figure 1.6

What is your interpretation?

A. Reverberation artifact, pulmonary edema
B. Lung pulse, no pneumothorax
C. Lung point, pneumothorax
D. Mirror artifact, normal

18. A 38-year-old male with a history of asthma presents to the ED with 2 days of chest pain and shortness of breath. His symptoms began after a mild upper respiratory tract infection. Vital signs are T 37.8, HR 95, RR 22, BP 135/90, and O_2 96% on RA. On exam, there are bilateral end-expiratory wheezing. You obtain a ultrasound, shown in Figure 1.7 and Video 1.7.

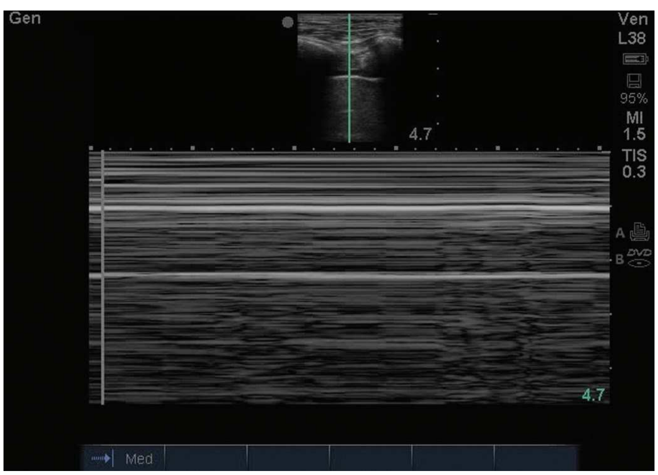

Figure 1.7

Which of the following is the most appropriate next step in management?

A. Perform a needle decompression.
B. Perform a tube thoracostomy.
C. Begin treatment for likely asthma exacerbation and order a chest X-ray.
D. Order a CT scan of the chest.

19. A 32-year-old male is brought in by ambulance after a high-speed motor vehicle collision. He is awake and alert and complaining of mild abdominal pain. Vital signs are HR 100, BP 110/85, RR 20, and O_2 100% on RA. You obtain the image shown in Figure 1.8 and Video 1.8 on suprapubic FAST window.

Figure 1.8

What is the next best step in the management of this patient?

A. Go to the OR for exploratory laparotomy.
B. Obtain a CT abdomen/pelvis.
C. Obtain a sagittal ultrasound view of the suprapubic region.
D. Place a pelvic binder.

20. Where does fluid tend to accumulate first in the LUQ or perisplenic view?

A. Inferior tip of the spleen
B. Splenorenal recess
C. Subdiaphragmatic space
D. Pancreatic duodenal recess

21. A 28-year-old male is brought to the ED with a gunshot wound to the chest. You obtain the following subxiphoid image (Figure 1.9, Video 1.9).

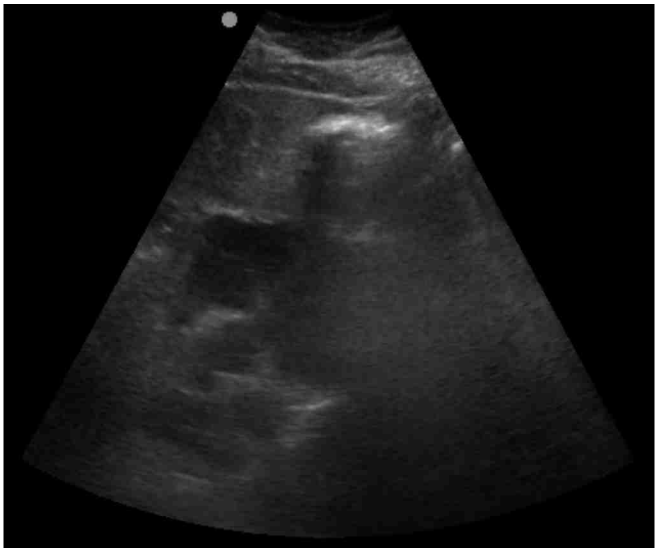

Figure 1.9

Which of the following would best optimize your visualization of the heart?

A. Switch to the sagittal orientation.
B. Slide the probe to the patient's right to use the liver as an acoustic window.
C. Place the patient in right lateral decubitus.
D. Place the probe more perpendicular to the patient's skin.

22. Which of the following pathologies can be associated with a positive FAST showing intraabdominal fluid?

A. Ruptured ectopic
B. Ruptured abdominal aortic aneurysm
C. Undifferentiated hypotension
D. All of the above

23. Paramedics bring a 23-year-old male to the ED after a head-on vehicle collision with another vehicle. Vital signs are HR 100, BP 135/90, RR 22, and O_2 saturation

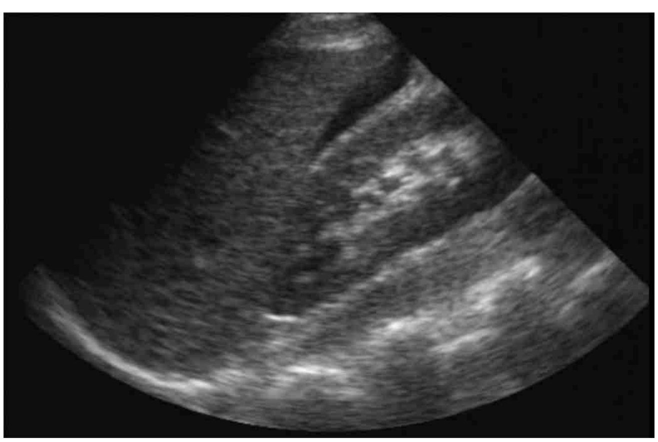

Figure 1.10

of 100%. He is awake and alert with mild abdominal tenderness to palpation, without rebound tenderness, guarding, or rigidity. You obtain the following FAST (Figure 1.10, Video 1.10).

What is the next best step in management?

A. Obtain a CT scan of the abdomen/pelvis.
B. Transfer to the OR for exploratory laparotomy.
C. Perform a diagnostic peritoneal lavage.
D. Initiate massive transfusion protocol.

24. A 54-year-old woman presents with abdominal pain after being involved in a side-impact vehicle collision. Her vital signs are BP 160/90, HR 112, RR 20, and O_2 saturation of 96% on RA. She is alert and oriented and has mild, diffuse abdominal tenderness with no rebounding or guarding. Her RUQ FAST window is shown in Figure 1.11 and Video 1.11.

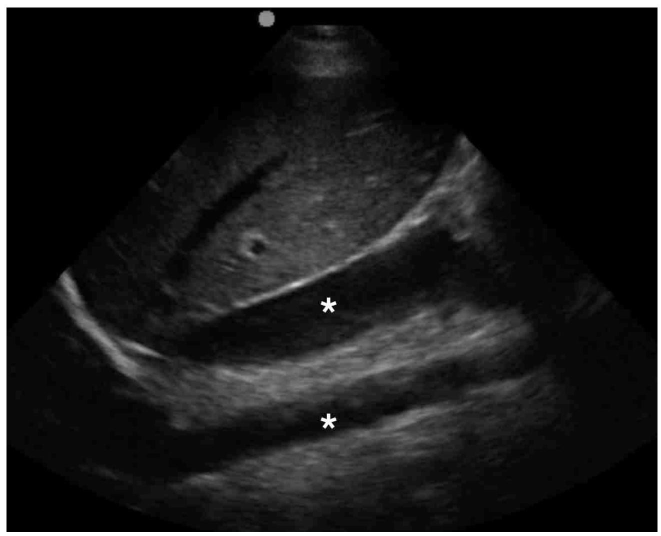

Figure 1.11

What is your interpretation of the anechoic stripe(s)?

A. Free fluid in the RUQ
B. Right-sided hemothorax
C. Inferior vena cava and aorta
D. Abdominal aortic aneurysm

25. A 67-year-old man presents with a history of liver cirrhosis presents with worsening abdominal pain and abdominal distension for the past week. His vital signs are BP 115/70, HR 88, RR 17, and O_2 saturation of 95% on RA. He is alert and oriented and has moderate right abdominal tenderness with no rebounding or guarding. His RUQ FAST window is shown in Figure 1.12 and Video 1.12.

Figure 1.12

What are the likely causes of the anechoic regions?

A. Free fluid in the RUQ
B. Renal cyst
C. IVC and aorta
D. A and B

26. A 26-year-old male is brought in by paramedics with a stab wound to the left abdomen. His vital signs are HR 105, BP 115/85, RR 24, and O_2 saturation of 100% on RA. On exam, you note a 1 centimeter wound to the left of the umbilicus, with moderate diffuse tenderness to palpation but no rebound or rigidity. You obtain a LUQ image (Figure 1.13, Video 1.13).

Figure 1.13

Which of the following statements is most accurate?

A. There is free fluid so the patient should immediately be taken to the OR.
B. The fluid present is within the stomach.
C. This is a common presentation of a splenic laceration.
D. The patient has a hemothorax.

27. A 30-year-old female presents with chest pain that started 2 days ago. She is usually healthy but has had an upper respiratory infection for the past week. Her vital signs are BP 130/70, HR 88, T 37.6, RR 16, and O_2sat 100% on RA. A point of care ultrasound was performed (Figure 1.14, Video 1.14).

Figure 1.14

What is found on the image?

A. Pericardial effusion
B. Pleural effusion
C. Epicardial fat pad
D. Right heart strain

28. A morbidly obese 24-year-old female presents with abdominal pain and vaginal bleeding. She had an ultrasound showing a normal intrauterine pregnancy 2 days ago. Her vital signs are BP 120/60, HR 88, RR 24, and O_2 saturation of 100%. A FAST exam was performed (Figure 1.15, Video 1.15).
What is your interpretation?

A. Free abdominal fluid in Morison's pouch
B. Perinephric fat without free abdominal fluid
C. Hepatic vein mimicking free abdominal fluid
D. Bowel contents

29. A 47-year-old obese female with a history of COPD, breast cancer, and coronary artery disease presents to the ED with acute onset shortness of breath and chest pain. She appears ill and diaphoretic and can only speak in short sentences. Her vital signs

Figure 1.15

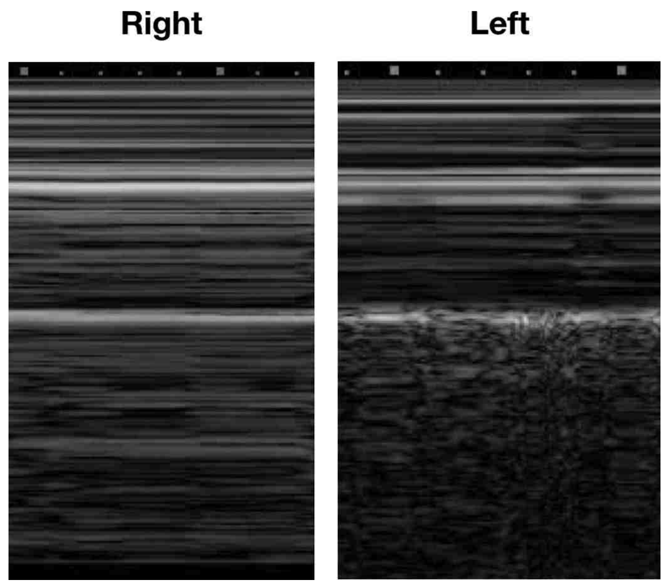

Figure 1.17 **M-mode view for lung sliding assessment of right and left thorax.**

are HR 115, BP 86/52, RR 32, T 37.5, and O_2 saturation of 93% on RA. She has a short, fat neck, making it difficult to assess for jugular venous distension. Her heart sounds are tachycardic and distant but so are her breath sounds. You think they are slightly more diminished on the right. Her abdominal exam is benign. You decide to perform an EFAST exam (Figure 1.16, Figure 1.17).

What is the most likely etiology of this patient's hypotension?

A. Cardiac tamponade
B. Ruptured abdominal aortic aneurysm
C. Sepsis
D. Tension pneumothorax

30. A 49-year-old woman with a past medical history of metastatic small cell lung cancer on chemotherapy presents with increased work of breathing for the past 3 hours. She is tachycardic and tachypneic. Her breath sounds appear diminished on the left base. You perform an EFAST exam (Figure 1.18, Video 1.16, Video 1.17).

What is the finding on ultrasound?

A. Pericardial effusion
B. Peritoneal fluid
C. Pleural effusion
D. Normal lung ultrasound

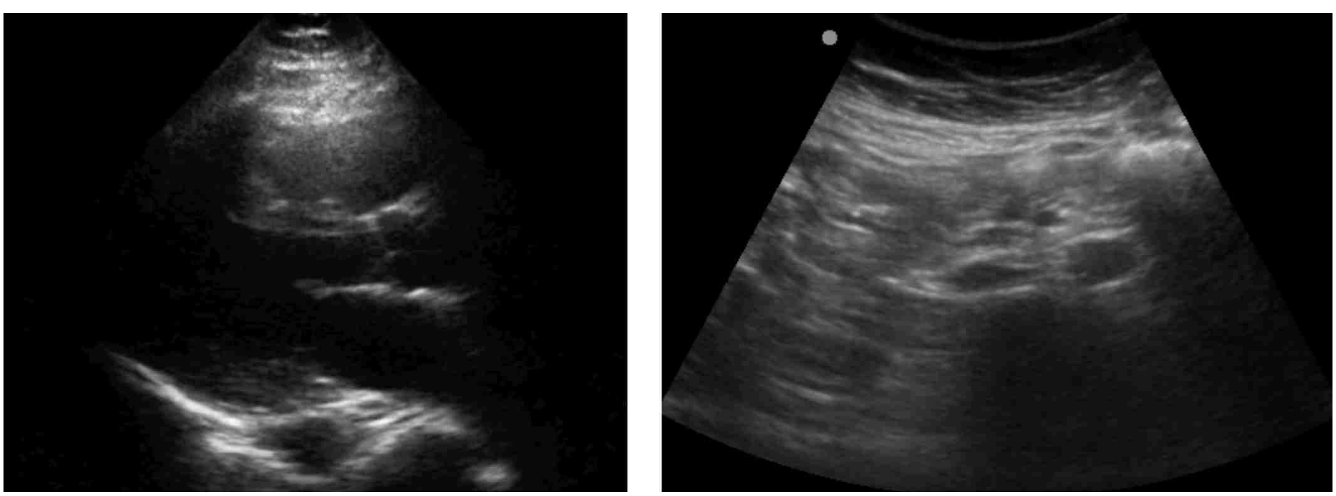

Figure 1.16 **Left panel: parasternal long axis view. Right panel: short axis view of inferior vena cava and aorta.**

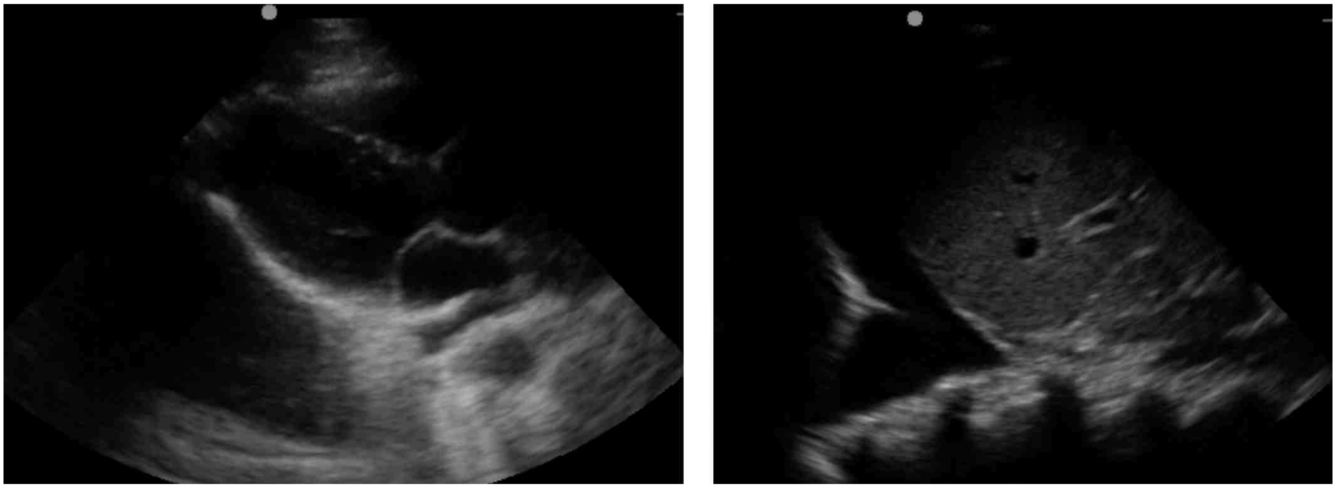

Figure 1.18

31. A 31-year-old woman presents with lower abdominal pain for 1 day. Her last menstrual cycle was 8 weeks ago, and she had a positive home pregnancy test 1 week ago. She appears in mild distress, but her vital signs are stable, and her abdominal exam shows mild lower abdominal tenderness without guarding or rebounding. Her pelvic exam shows a closed os, empty vaginal vault, and no tenderness elicited on the bimanual exam. You perform this suprapubic view of the FAST exam (Figure 1.19, Video 1.18).

What is your next best step?

A. Call ObGyn to prepare the OR for emergent exploration.
B. Type and cross the patient.
C. Treat the patient for pelvic inflammatory disease,
D. Use color Doppler.

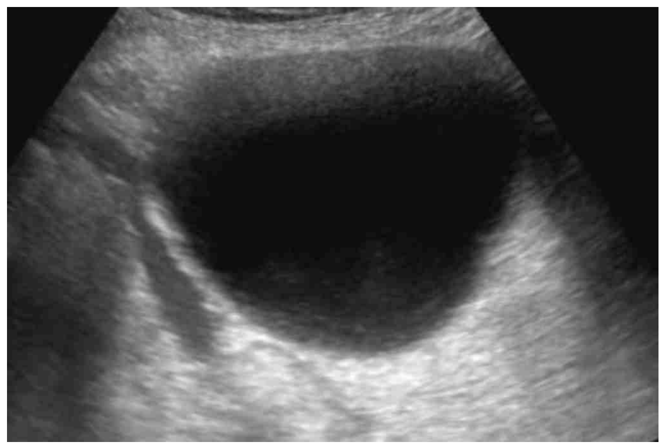

Figure 1.19

ANSWERS

1. EXPLANATION

D. Go to operating room (OR) for an exploratory laparotomy. Unstable trauma patients with penetrating abdominal trauma should go immediately to the OR for definitive treatment, regardless of findings on the FAST exam. The images in Figure 1.1 show normal views of the right upper quadrant (RUQ), left upper quadrant (LUQ), and suprapubic. Note that sometimes the seminal vesicles in the suprapubic window can be confused for free fluid. While the FAST has a specificity of 95% for hemoperitoneum in trauma patients, its sensitivity ranges between 22% and 100%, depending on the mechanism of abdominal trauma and the volume of fluid present in the peritoneum. Thus, the sensitivity of the FAST increases in patients who are hemodynamically unstable from penetrating abdominal trauma. As penetrating trauma may lead to retroperitoneal injuries that are not assessed with the FAST exam, any penetrating trauma patients with hemodynamic instability and a negative FAST warrant further assessment, most definitively with an exploratory laparotomy. Labs, CT scan, and serial exams may be warranted in stable trauma patients but must not interfere with the evaluation and treatment offered by exploratory laparotomy.

Learning Points: A hypotensive patient with evidence of abdominal trauma but a negative FAST should go to the OR for exploratory laparotomy.

FURTHER READING

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Keywords/Tags: FAST, unstable, penetrating trauma

2. EXPLANATION

A. Perform a CT scan of the abdomen and pelvis. In a stable trauma patient with blunt abdominal trauma, the patient should proceed to the CT scanner after a negative FAST exam, especially if a high-energy mechanism is involved. The sensitivity of the FAST in hemodynamically stable patients is mixed. In one article, the sensitivity of the FAST in hemodynamically stable patients was as low as 43%. For example, Carter showed a 15% false-negative FAST exam rate in stable patients with CT-confirmed intra-abdominal injuries that required operative intervention. However, if all patients in that study were included (n = 1671), the false-negative rate requiring intervention was 1%. Miller found that the negative predictive value was 93%, accuracy was 92%, and less than 2% of patients with a false negative FAST required operative intervention. In studies where the FAST was found to be negative but either CT or exploratory laparotomy was found to be positive, the injuries are usually isolated to organ or bowel, both injuries of which the FAST was not designed to capture.

Learning Points: The FAST exam is insensitive for solid organ and hollow viscous injuries, so a stable trauma patient should receive additional imaging and/or serial exams after a negative initial FAST exam.

FURTHER READING

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Carter JW, Falco MH, Chopko MS, Flynn WJ Jr, Wiles III CE, Gup WE. Do we really rely on fast for decision-making in the management of blunt abdominal trauma? *Injury*. 2015;46(5): 817–821.

Keywords/Tags: FAST, stable, blunt trauma

3. EXPLANATION

A. Within Morison's pouch. Of all four views of the FAST, the RUQ view is the most sensitive in detecting free fluid. A low-frequency curvilinear or phased array probe can be used. Place the probe in the coronal orientation along the mid-axillary line over the 8th to 11th intercostal spaces of the ribs (Figure 1.20). Visualization of the liver in this view decreases the interference caused by air-filled bowel. Move the probe inferiorly to visualize the liver tip (which represents the subdiaphragmatic space) and posteriorly to visualize the pole of the right kidney, which represents the paracolic gutter. The space visualized in between the liver and kidney is Morison's pouch. Slide the probe cephalad and caudad as well to fully visualize the tips of both the liver and kidney and to expose the diaphragm as it meets the spine to assess for the presence of pleural fluid (Figure 1.21, Video 1.19). In a normal FAST, the region above the diaphragm is air-filled lung. Air will reflect ultrasound waves from adjacent structures like the liver, causing mirror artifact, which also prevents visualization of the spine past the diaphragm. If fluid is present in the thorax, the mirror image is lost and anechoic liquid is visualized. Because fluid

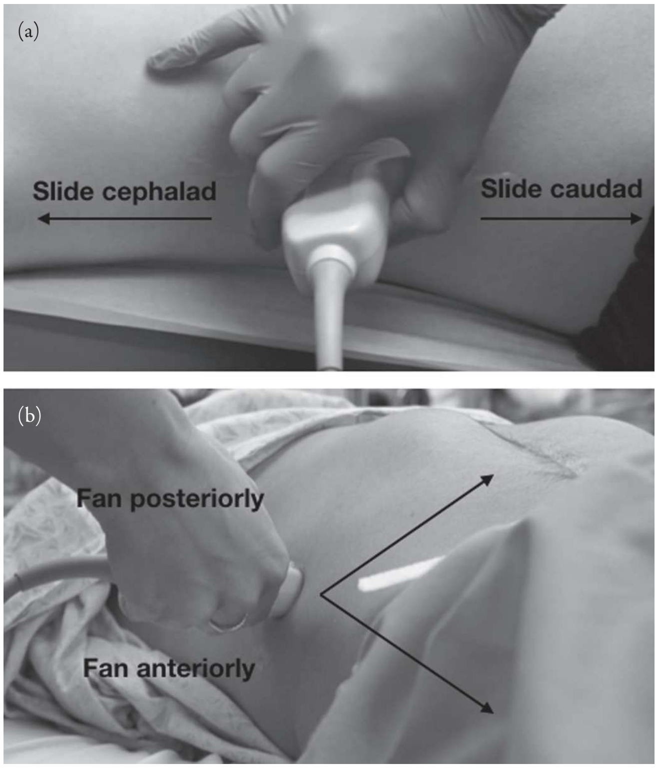

Figure 1.20 **Placement of probe on right upper quadrant and associated movements.** Sliding the probe cephalad will help to assess for fluid underneath the diaphragm as well as pleural effusions. Sliding the probe caudad will help to assess for fluid in the right paracolic gutter near the inferior liver tip and inferior pole of the kidney (Panel A). Note that the curvilinear probe used is slightly rotated posteriorly to align the scan plane with the intercostal space, which will reduce rib shadowing. Fanning or tilting the probe anteriorly will often demonstrate bowel gas from the adjacent duodenum, while fanning or tilting the probe posteriorly will demonstrate the hepatorenal space or Morison's pouch (Panel B).

has now replaced air-filled lung parenchyma, the underlying spine can be seen across the entire trajectory of the screen. When this happens, it is called the "spine sign" (Figure 1.22, Video 1.20).

Learning Points: Fluid can accumulate in the right paracolic gutter, hepatorenal space, and/or subdiaphragmatic space in the RUQ window of the FAST.

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Keywords/Tags: FAST, trauma, right upper quadrant, RUQ, spine sign, liver tip

4. EXPLANATION

C. Deflate the balloon and pull the endotracheal tube back. The patient's lung ultrasound findings were a result of a right mainstem bronchus intubation. If the initial EFAST was normal and a second EFAST after intubation showed normal lung movement on the right but no lung

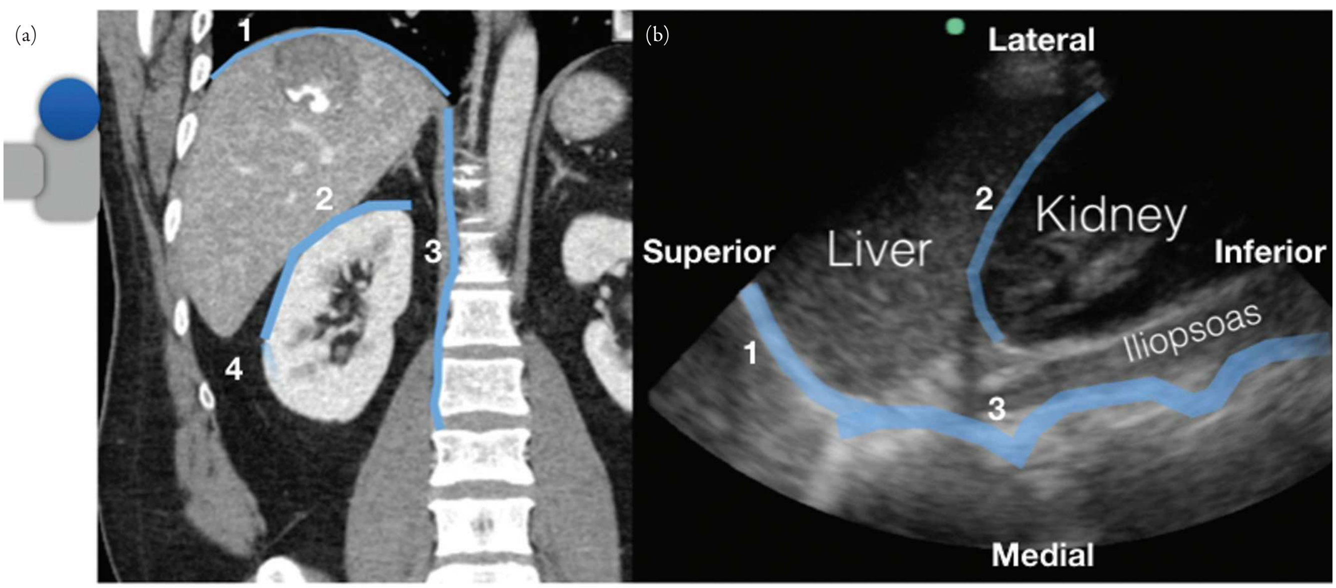

Figure 1.21 **Potential places for free fluid in right upper quadrant (RUQ) view.** There are three major hyperechoic lines to visualize in the RUQ view. Fluid can be seen above and below the diaphragm, seen as the first line (1). Perinephric fat is seen as the second line (2); fluid in Morison's pouch is seen between this line and the liver. The third line (3) shows the vertebral column, which will be visualized above the diaphragm if a pleural effusion is present. Peritoneal fluid in the RUQ will typically accumulate first in the right paracolic gutter (4), and then travel anteriorly and medially into the hepatorenal space.

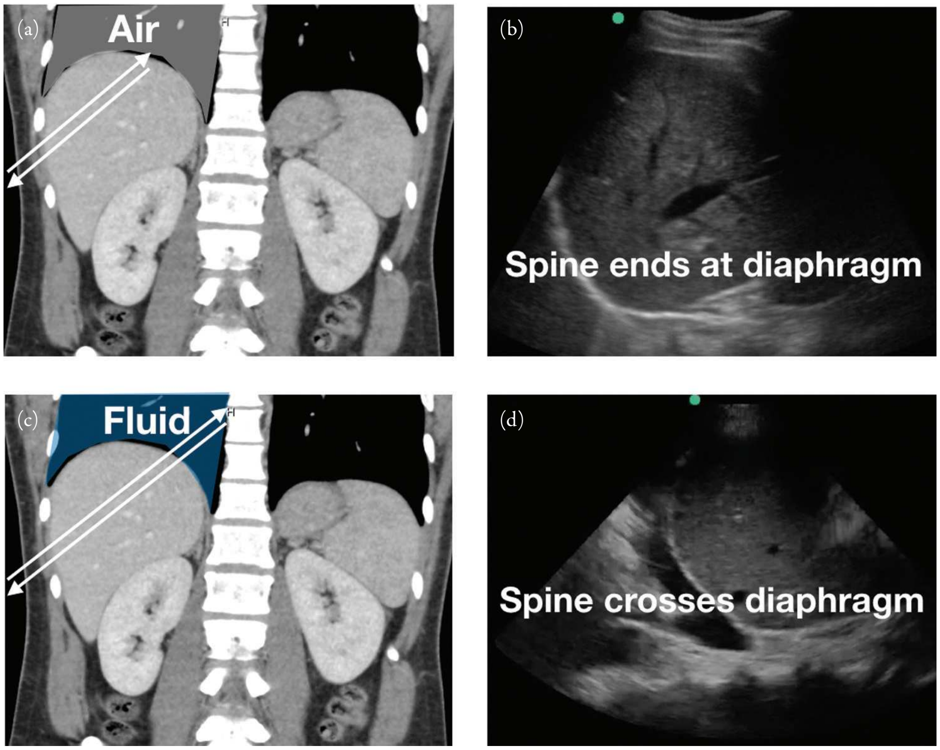

Figure 1.22 **Anatomical basis for spine sign.** In a normal air-filled hemithorax, soundwaves are scattered by air molecules within lung, and thus do not reflect off the thoracic vertebrae above the diaphragm (Panels A and B). A pleural effusion allows soundwaves to travel between diaphragm and the thoracic vertebral column. The resultant echo is seen as the vertebral bodies above the diaphragm, also known as the "spine sign" (Panels C and D).

movement on the left, the presence of a lung pulse as a result of a right mainstem intubation should be considered along with pneumothorax in this patient. Lung pulse is defined as a subtle, rhythmic movement of the parietal and visceral pleura apposing each other as cardiac motion is transmitted through the lung. On M-mode it can be seen as subtle bands of movement (Figure 1.23, Video 1.21). It should not be seen in a pneumothorax. Lung pulse will help to differentiate a right bronchial mainstem intubation from a pneumothorax.

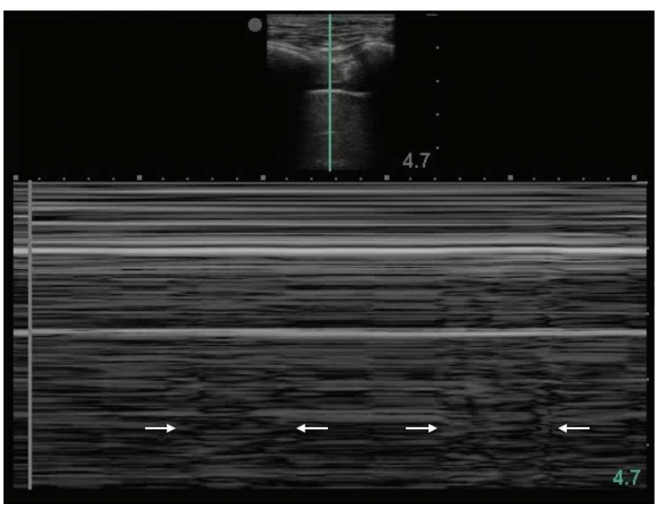

Figure 1.23 **Lung pulse on M-mode imaging.** Notice the subtle bands that appear periodically and break-up the contiguous lines below the pleura that are associated with pneumothorax. These bands are caused by the lung pulse, which are not seen in pneumothorax.

Learning Points: A right mainstem bronchus intubation can lead to absence of pleural sliding of the left thorax. The lung pulse sign can help to distinguish from a pneumothorax.

FURTHER READING

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Keywords/Tags: Lung pulse, lung sliding

5. EXPLANATION

B. The sensitivity of FAST is low especially if only a small volume of hemoperitoneum is present. The volume of fluid present and the location of the fluid within the peritoneum determine how easily free fluid

will be detected on FAST. In the hepatorenal view, free fluid will be seen first in the paracolic gutter, along the inferior pole of the kidney. The suprapubic space is also a more sensitive region to look for small free fluid on FAST. In the perisplenic view, free fluid is more difficult to detect, due to the size and location of the spleen, which is more superior and posterior than the liver, the fact that the sonographer is on the opposite side of the patient and must physically reach over to scan the perisplenic view, and the presence of other abdominal structures such as the stomach, which can obscure the view. Although the suprapubic region may theoretically be the most sensitive place to look for free fluid as it is the most dependent, the literature does not support this. The presence of organs, vessels, and other anatomical structures in the pelvis can prevent the sonographer from seeing small pockets of free fluid. In addition, injury patterns for both blunt and penetrating trauma lead to more common positive hepatorenal exams. Also, the bladder and the amount of posterior acoustic enhancement generated may decrease sensitivity. Looking at the bladder in the sagittal orientation may improve sensitivity and allow an unobstructed posterior view of the pelvic space.

Several studies have looked at the minimum amount of free fluid necessary for it to be detected on FAST. Although some studies have noted ultrasound's ability to detect as little as 100 milliliter (mL) of fluid in the peritoneum, more recent studies have noted that larger volumes, between 400 mL and 600 mL are necessary to properly visualize free peritoneal fluid on FAST.

Learning Points: The pelvis is the most dependent region in the peritoneum, but fluid will accumulate and localize according to the injury pattern.

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Keywords/Tags: FAST, peritoneal fluid, pelvic, suprapubic, sensitivity

6. EXPLANATION

A. Are hypoechoic or hyperechoic. Echogenicity is an object's ability to reflect ultrasound waves based on the level of acoustic impedance in tissues. Visually, it describes how bright or dark an object is compared to its surrounding structures on ultrasound. A structure can be hyperechoic (bright), hypoechoic (grey), or anechoic (black). Free-flowing blood is anechoic on ultrasound because all the ultrasound waves in the beam move through the fluid and none of them are reflected back to the transducer. Hyperechoic tissue causes a strong reflection of sound waves back to the transducer, resulting in a bright image. Solid structures such as bone are hyperechoic on

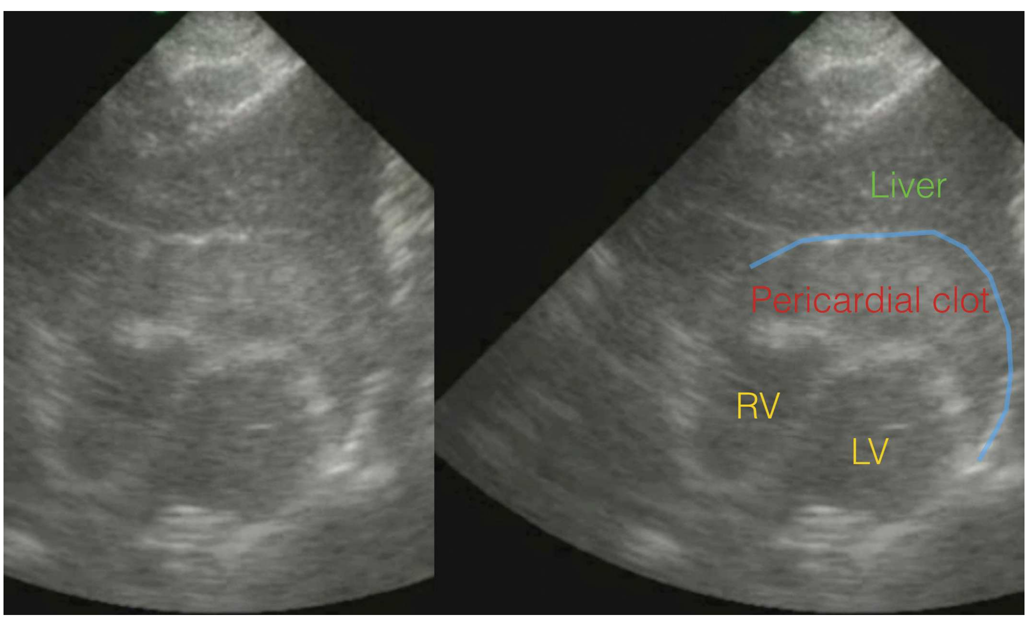

Figure 1.24 **Pericardial thrombus.** Note that the fibrous and visceral pericardial layers are separated by the echogenic thrombus on this subxiphoid window.

ultrasound. As blood clots form and solidify, their echogenicity increases with time (Figure 1.24).

FURTHER READING

Laselle BT, Kendall JL. Trauma. In: Cosby KS, Kendall JL, eds. *Practical Guide to Emergency Ultrasound*. 2nd ed. Philadelphia, PA: Lippincott, Williams and Wilkins; 2014:34–37.

Keywords/Tags: Clot, thrombus, echogenicity

7. EXPLANATION

C. Perform a CT scan of the abdomen and pelvis. Ultrasound lacks the ability to elucidate acoustic fluid characteristics when present in the abdomen. Therefore, ascites, bowel contents, urine, bile, and blood all appear similarly on ultrasound. While the liver contour in the image is rough and suggestive of cirrhosis, ascites may not be the etiology of his free fluid. The patient is able to protect his airway and is hemodynamically stable. Therefore, he should receive a CT scan to assess for vascular or organ injuries and determine if a source of bleeding is present. In addition, a diagnostic peritoneal lavage or diagnostic paracentesis may be performed to further elucidate the etiology of fluid.

Learning Points: Ascitic fluid will lead to a positive FAST exam, so CT imaging can help to evaluate for solid organ injury and elucidate the etiology of peritoneal fluid. In addition, peritoneal fluid analysis can be performed.

FURTHER READING

Laselle BT, Kendall JL. Trauma. In: Cosby KS, Kendall JL, eds. *Practical Guide to Emergency Ultrasound*. 2nd ed. Philadelphia, PA: Lippincott, Williams and Wilkins; 2014:40–42.

Whitehouse JS, Weigelt JA. Diagnostic peritoneal lavage: a review of indications, technique, and interpretation. *Scand J Trauma Resusc Emerg Med*. 2009;8(17):13.

Keywords/Tags: CT, FAST, ascites, blood

8. EXPLANATION

D. Admit for monitoring/serial abdominal exams given the concern for possible delayed bowel injury. The FAST exam was designed to detect hemoperitoneum in patients with suspected abdominal trauma (Figure 1.25). Significant diaphragmatic, bowel, mesenteric, and solid organ injury may present without hemoperitoneum. Additionally, the FAST was not designed to detect free fluid in the retroperitoneum. CT is also insensitive for diaphragmatic, bowel, and mesenteric injuries. Thus, while the overall incidence of delayed injuries is low, patients with a concerning injury mechanism but negative CT and FAST can be admitted for serial abdominal exams and repeat CT if indicated. This may be a preferred option for pediatric trauma patients, as their exams can be unreliable.

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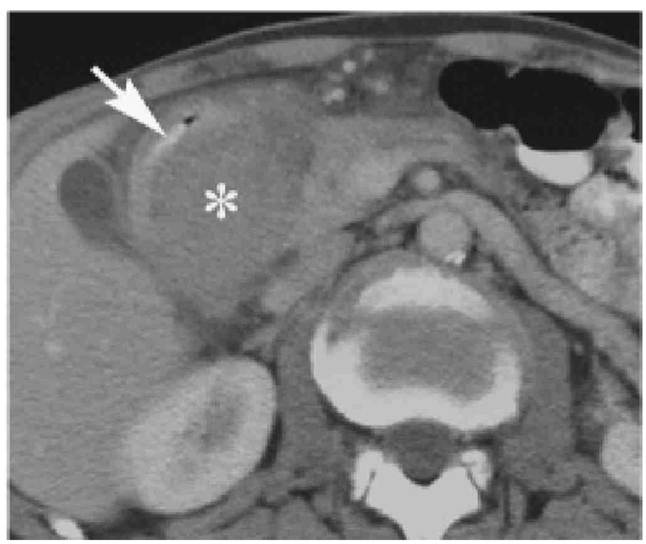

Figure 1.25 **Repeat CT scan of the patient with worsening exam findings show duodenal contusion with adjacent hematoma (*).** No free air is seen. From Figure 37.4 of Levy AD, Mortele K, Yeh BM, eds. *Gastrointestinal Imaging Cases*. Oxford, UK: Oxford University Press; 2013.

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Stawicki S. Trends in nonoperative management of traumatic injuries—a synopsis. *Int J Crit Illn Inj Sci*. 2017;7(1):PMC5364768.

Keywords/Tags: Small bowel injury, delayed presentation

9. EXPLANATION

B. Place patient in Trendelenburg position. Placing the patient in Trendelenburg on the gurney allows gravity to pull free peritoneal fluid in the abdomen toward the diaphragm. In patients with suspected free fluid in the pelvis, reverse Trendelenburg will pull free peritoneal fluid into the dependent region of the pelvis. Several studies have looked at the minimum amount of free fluid necessary for the FAST to be positive. In one study, over 600 mL was present before it was detected on FAST; however, detection was noted with the presence of 400 mL when the patient was placed in Trendelenburg.

Learning Points: Patients can be placed in Trendelenburg position to increase the sensitivity of the FAST exam when the suspected etiology is a liver or splenic injury. Patients can be placed in reverse Trendelenburg position when the suspected etiology is a pelvic vessel injury.

FURTHER READING

Jehle DVK, Stiller G, Wagner D. Sensitivity in detecting free intraperitoneal fluid with the pelvic views of the FAST exam. *Am J Emerg Med*. 2003;21(6):476–478.
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Keywords/Tags: Pelvic, FAST, ultrasound, sensitivity, Trendelenburg

10. EXPLANATION

D. B and C. A phased array or curvilinear probe should be used to evaluate the abdomen for intra-abdominal free fluid because both generate low frequency soundwaves that can penetrate more deeply into the abdomen (Figure 1.26). The

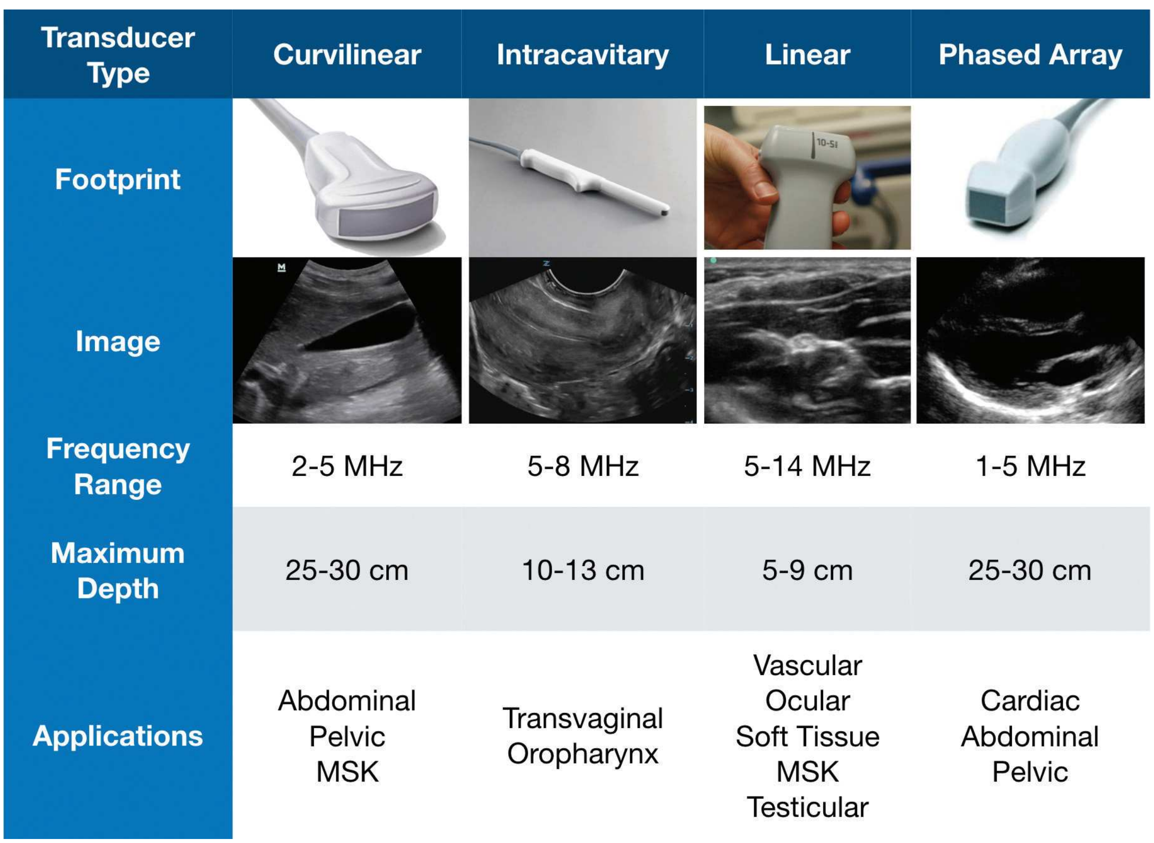

Figure 1.26 **Transducer types and their clinical applications.** From Figure 3.5 of Chiem A. Transducers. In: Soni N, Arntfield R, Kory P, eds. *Point-of-Care Ultrasound*. 1st ed. Philadelphia, PA: Elsevier Saunders; 2015:22.

curvilinear transducer has more piezoelectric elements that can give improved resolution, while the phased array transducer has a smaller footprint that can be useful for intercostal imaging. A linear probe has a higher frequency range, and thus attenuation limits imaging to less than 5 to 10 centimeter in depth, making it unsuitable for adult abdominal imaging.

FURTHER READING

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Keywords/Tags: Phased array, curvilinear, FAST, ultrasound

11. EXPLANATION

D. Hemothorax, spine sign. In a normal FAST, the region above the diaphragm (thorax) consists of an air-filled lung. Air will reflect ultrasound waves from adjacent structures like the liver, causing mirror artifact, which also prevents visualization of the spine past the diaphragm. If fluid is present in the thorax, the mirror image is lost, and anechoic fluid is visualized. Because fluid has now replaced what is normally air-filled lung parenchyma, the underlying spine can be seen across the entire trajectory of the screen. When this happens, it is called the "spine sign."

> **Learning Points:** A spine sign is visualization of the vertebral column above the diaphragm, which signifies a pleural effusion or hemothorax.

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Ahmed AA, Martin JA, Saul T, Lewiss RE. The thoracic spine sign in bedside ultrasound: three case reports. *Med Ultrason*. 2014;16(2):179–181.
Dickman E, Terentiev V, Likourezos A, Derman A, Haines L. Extension of the thoracic spine sign: a new sonographic marker of pleural effusion. *J Ultrasound Med*. 2015;34(9):1555–1561.

Keywords/Tags: Spine sign, hemothorax

12. EXPLANATION

B. Obtain a parasternal long axis view of the heart. When you are unable to view the 4 chambers of the heart from the subxiphoid approach, the best next step is to obtain a parasternal long axis view. The parasternal long axis view offers an unobscured view of the free walls of the left atrium and left ventricle, as well as the right ventricle. A true parasternal long axis view allows visualization of the aortic and mitral valves but not the apex of the left ventricle or the right atrium. Simple pericardial effusions will be dependent and therefore visualized first along the posterior pericardium, and then track to the anterior pericardium with increasing volume (see Figure 2.2, Video 2.2).

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Keywords/Tags: Parasternal long axis, FAST, ultrasound

13. EXPLANATION

D. All of the above. The LUQ is typically a more technically difficult view to obtain for several reasons (Figure 1.27). The first is that the sonographer must reach over the patient's body to access the LUQ, which can be physically difficult in larger patients. Next, the location of the spleen is posterior and cephalad and, due to its smaller size, can often be obscured by rib shadowing. Last, the spleen displays a smaller acoustic window so the clarity of the surrounding structures may be decreased. Placing the probe posterior and cephalad such that the knuckles of the sonographer are touching the bed and rotating the probe face so that it is nestled along the trajectory of the intercostal spaces will improve the image quality of the spleen and surrounding structures and decrease the presence of rib shadowing.

> **Learning Points:** Place the transducer more posterior and superior than the contralateral RUQ window to image the perisplenic space. Fluid can accumulate in the subphrenic space before the splenorenal space, so imaging the medial spleen is crucial.

FURTHER READING

Laselle BT, Kendall JL. Trauma. In: Cosby KS, Kendall JL, eds. *Practical Guide to Emergency Ultrasound*. 2nd ed. Philadelphia, PA: Lippincott, Williams and Wilkins; 2014:42.
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Keywords/Tags: FAST, RUQ, ultrasound

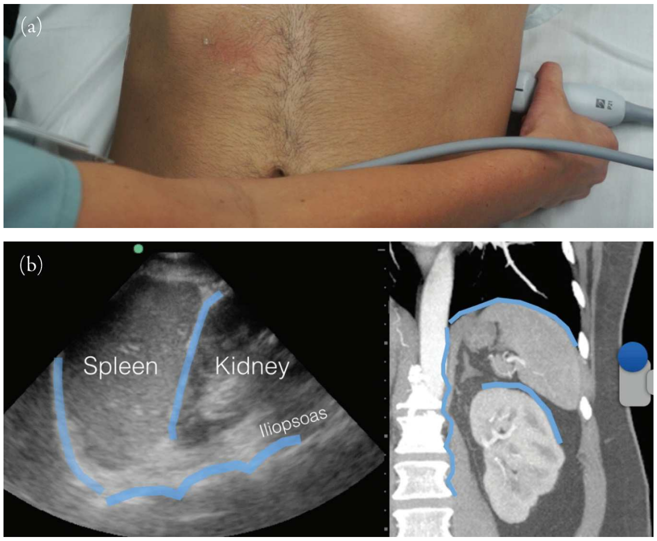

Figure 1.27 (a) **Positioning for perisplenic imaging on the FAST exam.** The spleen is more cephalad and posterior than the liver, so often the sonographer has to move up 1 intercostal space and fan or slide the probe more posteriorly. (b) **Perisplenic view.** There are 3 potential areas where fluid will accumulate: below the diaphragm in the subphrenic space, in the splenorenal recess, and, more infrequently, the inferior pole of the kidney. The subphrenic space is often the most sensitive for detecting perisplenic fluid, but it can be difficult to image because the stomach sits on top or anterior to the medial tip of the spleen. To image this space, the sonographer has to fan the probe posteriorly. Also note that the spleen provides a much smaller acoustic window than the liver. This is one reason that the left upper quadrant window is the most difficult to obtain on the FAST exam.

14. EXPLANATION

B. Scatter artifact. Scatter artifact occurs when a sound wave strikes a structure with both a different density or dimension and a smaller wave amplitude. When a sound wave from the transducer meets an air molecule, it causes the ultrasound waves to scatter in all directions, hence the "scattering" of multiple echoes. While conventional teaching describes "clean shadowing" as emanating from dense structures like bone, and "dirty shadowing" from air, Rubin demonstrated that the type of shadowing is not related to the density of the object but is related to its curvature and the smoothness of the object's surface. Dirty shadowing tends to come from objects with smooth surfaces and larger radius, while smooth shadowing tends to come from objects with rough surfaces and smaller radius.

Learning Points: Dirty shadowing is a type of scatter artifact that occurs when imaging air, either due to subcutaneous emphysema or in bowel gas.

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Keywords/Tags: Scatter artifact scattering, pneumothorax, EFAST

15. EXPLANATION

D. Proximal aorta window. The traditional FAST exam was first described by Rozycki for the evaluation of hemoperitoneum by surgeons in traumatic presentations. This is one of the first point-of-care ultrasound exams described by nonradiologists or noncardiologists. The traditional views of the FAST include RUQ, LUQ, suprapubic, and subxiphoid views. The EFAST was described by Kirkpatrick et al., also to evaluate pneumothorax and hemothorax, in addition to hemoperitoneum. The application of both exams has been extended to evaluate for nontraumatic causes of hemoperitoneum like ruptured ectopic pregnancy or ruptured abdominal aortic aneurysm (AAA). In addition, the EFAST can be used to evaluate for pleural effusions in addition to nontraumatic causes of pneumothorax.

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Rozycki GS, Ochsner MG, Jaffin JH, Champion HR. Prospective evaluation of surgeons' use of ultrasound in the evaluation of trauma patients. *J Trauma*. 1993;34(4):516–526; discussion 526–527.

Rozycki GS, Shackford SR. Ultrasound, what every trauma surgeon should know. *J Trauma*. 1996;40(1):1–4.

Keywords/Tags: EFAST, FAST

16. EXPLANATION

A. Linear probe, because it is a high frequency probe. The pleura is a superficial structure and thus historically best visualized with a high frequency (8–12 MHz) linear probe. Higher frequency probes provide better resolution for superficial structures such as the pleura, blood vessels, and the eye. A linear probe can provide excellent images of lung sliding. More recently, literature has supported the use of lower frequency probes to evaluate the pleura for lung sliding during the EFAST. If equivalent, one would not need to change probes during the EFAST exam after performing the abdominal applications.

Learning Points: A linear probe is best for assessing for pleural sliding. However, low-frequency probes can be used by decreasing the depth and gain to better visualize the pleural interface.

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Tasci O, Hatipoglu ON, Cagli B, Ermis V. Sonography of the chest using linear-array versus sector transducers: correlation with auscultation chest radiography and computed tomography. *J Clin Ultrasound*. 2016;44(6):383–389.

Keywords/Tags: Linear probe, high frequency, lung sliding

17. EXPLANATION

C. Lung point, pneumothorax. The video shows a "lung point," which is nearly 100% specific for pneumothorax. In a pneumothorax, the visceral and parietal pleura are separated from each other. A lung point represents the point at which these two surfaces meet, that is, the interface between a pneumothorax and adjacent inflated lung (Figure 1.28). Absent lung sliding suggests pneumothorax but is not 100% specific. The lung pulse is the rhythmic movement due to cardiac mechanic activity and rules out a pneumothorax at the point where the probe is on the chest. Mirror artifact in thoracic ultrasound applies to both diaphragm and pericardium but is often normal. Reverberation artifact accounts for A-lines, which are reflections of the pleural interface. A-lines are normal and do not signify pulmonary edema.

Learning Points: The lung point is highly specific for pneumothorax, as it represents the border of normal pleural interface and separation of the pleural layers.

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Lichtenstein DA, Lascols N, Prin S, Mezière G. The "lung pulse": an early ultrasound sign of complete atelectasis. *Intensive Care Med*. 2003;29(12):2187–2192.

Keywords/Tags: Lung point, pneumothorax

18. EXPLANATION

C. Begin treatment for likely asthma exacerbation and order a chest X-ray. Although the ultrasound shows an absence of lung sliding, this is not 100% specific for a pneumothorax. Absent lung sliding can also be seen in a variety of conditions such as pleural adhesions, pleural blebs, apnea, asthma/chronic obstructive pulmonary disease (COPD) exacerbations, acute respiratory distress syndrome, atelectasis, and interstitial fibrosis.

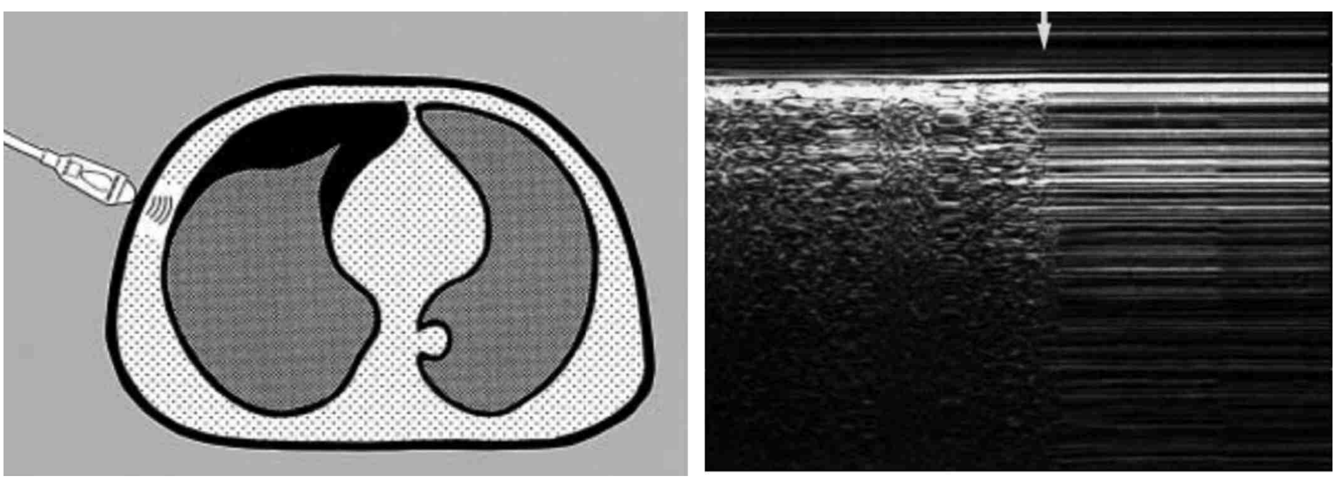

Figure 1.28 **The lung point sign on M-mode.** On the left side of the M-mode tracing, there is pleural sliding, but on the right side, there is no sliding. The pneumothorax starts at this transition point, as seen on the drawing on the left. Adapted from Figures 5 and 6 of Lichtenstein D, Mezière G, Biderman P, Gepner A. The lung point an ultrasound sign specific to pneumothorax. *Intensive Care Med*. 2000;26(10):1434–1440.

This patient is hemodynamically stable with bilateral breath sounds, and so it is appropriate to defer needle decompression or tube thoracostomy until a chest X-ray can be performed. In these cases, if the chest X-ray is nondiagnostic, then a CT scan of the chest may be warranted.

Learning Points: While absence of pleural sliding is highly sensitive for pneumothorax, it is nonspecific, with many other potential causes such as hyperinflation, pleural disease, and emphysema.

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Mallow C, Isakow W. Risk factors for loss of lung sliding in a medical intensive care population with acute respiratory failure. *J Bronchology Interv Pulmonol*. 2018. doi:10.1097/LBR.0000000000000525

Slater A, Goodwin M, Anderson KE, Gleeson FV. COPD can mimic the appearance of pneumothorax on thoracic ultrasound. *Chest*. 2006;129(3):545–550.

Keywords/Tags: Pneumothorax, asthma

19. EXPLANATION

C. Obtain a sagittal ultrasound view of the suprapubic region. In the male patient, seminal vesicles may be incorrectly interpreted as free fluid on FAST (Figure 1.29). A complete view of the suprapubic region involves both transverse and sagittal planes. In both planes, the seminal vesicles can be seen as cystic and thus not free fluid. In addition, the longitudinal view can be more sensitive for free fluid because free fluid outside the posterior bladder wall is easier to identify in this plane. Also, a transverse view may be obtained higher in the peritoneal cavity in cases of a very full bladder, therefore making it possible to miss free fluid in the most dependent part of the pelvis (the rectovesicular space).

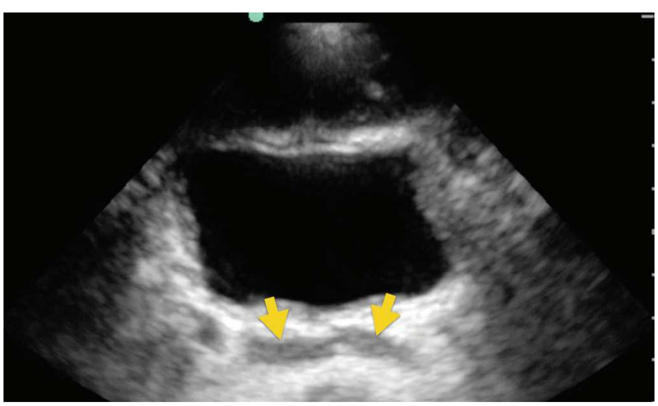

Figure 1.29 **Seminal vesicles.** Seminal vesicles will appear oval-shaped and can be discerned from free fluid by fanning and rotating to elucidate their cystic appearance. In addition, they typically are hypoechoic but not usually anechoic.

Learning Points: Seminal vesicles can be mistaken for pelvic free fluid. Fanning and rotating the probe will help to differentiate these cystic structures from free fluid.

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Keywords/Tags: False positives, seminal vesicles, suprapubic

20. EXPLANATION

C. Subdiaphragmatic space. Intraperitoneal fluid in the LUQ most commonly accumulates in the left subdiaphragmatic or subphrenic space first (Figure 1.30). This is due to the location of the phrenicocolic ligament, which can block the flow of fluid down the left paracolic gutter. Fluid can also migrate from the subphrenic space to the hepatorenal space before the splenorenal space as a result of the obstruction from the phrenicocolic ligament.

Figure 1.30 **Subdiaphragmatic fluid.** Note that there is no fluid in the splenorenal space, while there is an ample fluid stripe in the subdiaphragmatic or subphrenic space.

FURTHER READING

Richards JR, McGahan PJ, Jewell MJ, Fukushima, LC, McGahan JP. Sonographic patterns of intraperitoneal hemorrhage associated with blunt splenic injury. *J Ultras Med*. 2004;23(3):387–394.

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Keywords/Tags: LUQ, subdiaphragmatic space, subphrenic space, splenorenal recess

21. EXPLANATION

B. Slide the probe to the patient's right to use the liver as an acoustic window. Air and stomach contents can obscure the image by scattering the ultrasound beams before they reach the heart. In the media, A-lines are seen emanating from the bowel gas interface, thus obscuring the apex of the heart. By sliding the probe to the patient's right, one can use the left lobe of the liver as an acoustic window, which will make the heart easier to visualize. Switching to the sagittal orientation will produce a longitudinal image of the inferior vena cava (IVC). Placing the patient in the right lateral decubitus will bring stomach contents toward the probe. If the probe is placed perpendicular to the patient's body, deeper structures such as the aorta and IVC will be visualized. Angling the probe on the skin at a 30 to 45 degree angle will allow for better visualization of the heart (Figure 1.31).

> **Learning Points:** On the subcostal or subxiphoid window, the transducer should be placed slightly to the right and inferior to the patient's xiphoid process and angled toward the left shoulder to maximize use of the liver as an acoustic window.

FURTHER READING

Noble VE, Nelson BP. Focused Assessment with sonography in trauma (FAST). In: Noble VE, Nelson BP, eds. *Manual of Emergency and Critical Care Ultrasound*. 2nd ed. Cambridge, UK: Cambridge University Press; 2011:37–39.

Keywords/Tags: Subxiphoid, acoustic window

22. EXPLANATION

D. All of the above. The purpose of the FAST exam is to detect free intraperitoneal, intrathoracic, and pericardial fluid, usually in the setting of trauma. However, it can also be applied to nontraumatic conditions that result in free fluid accumulation in the peritoneum and thorax, such as ruptured ectopic pregnancy, ruptured abdominal aortic aneurysm, and in the evaluation of an undifferentiated hypotensive patient.

FURTHER READING

Noble VE, Nelson BP. Focused Assessment with sonography in trauma (FAST). In: Noble VE, Nelson BP, eds. *Manual of Emergency and Critical Care Ultrasound*. 2nd ed. Cambridge, UK: Cambridge University Press; 2011:27–57.

Javedani PP, Metzger S, Oulton J R, et al. Use of focused assessment with sonography in trauma examination skills in the evaluation of non-trauma patients. *Cureus*. 2018;10(1):e2076.

Keywords/Tags: Ectopic, abdominal aortic aneurysm, hypotension

23. EXPLANATION

A. Obtain a CT scan of the abdomen/pelvis. Hypotensive patients with a positive FAST exam should proceed straight to the OR for exploratory laparotomy. However, stable blunt trauma patients with a positive FAST should receive a CT. A CT scan will better elucidate the location and extent of injury present. CT is more reliable and sensitive than ultrasound in diagnosing and grading specific solid organ injuries. The most common solid organ injuries incurred from blunt abdominal trauma are to the liver and spleen. However, the most recent literature supports nonoperative

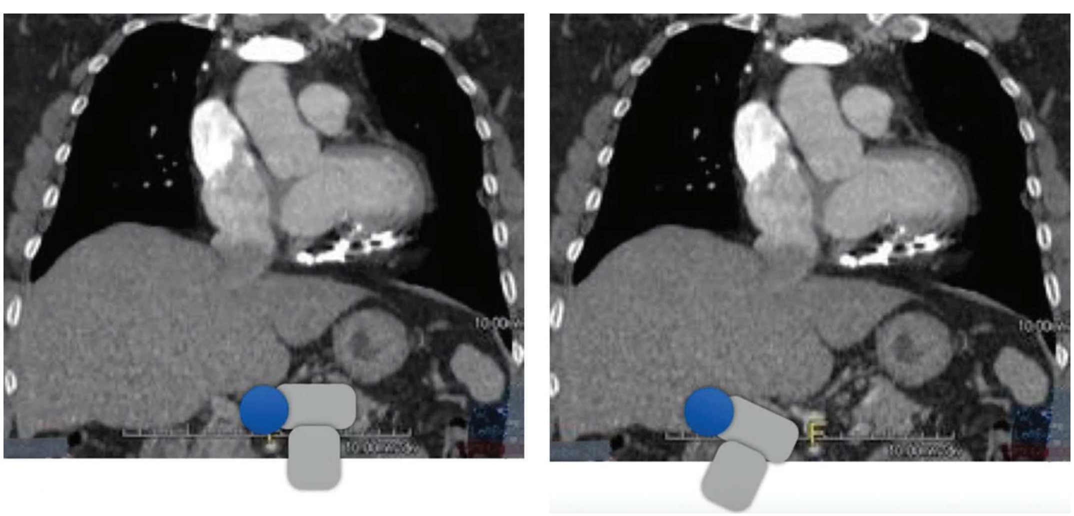

Figure 1.31 **Optimizing subxiphoid window.** The image on the left shows the ultrasound plane partially imaging through the liver, with the right edge of the plane directed at bowel. This leads to the partially obscured subxiphoid image. To optimize this window, direct the ultrasound plane so that it passes completely through the liver. To do this, slide the probe slightly to the patient's right and angle to the left shoulder.

management in many of these cases. Some guidelines recommend nonoperative management of blunt hepatic and splenic injuries in hemodynamically stable patients regardless of the grade of injury. A diagnostic peritoneal lavage is indicated in hemodynamically unstable patients or who require urgent surgery for extra-abdominal injuries. Its use has decreased significantly with the advent of the FAST exam and CT. Although a massive transfusion protocol may be warranted later for this patient, it is not the next step in management, as he is hemodynamically stable.

Learning Points: In stable trauma patients with a positive FAST, a CT should be performed to elucidate the source and extent of bleeding. This is because the vast majority of solid organ injuries is low grade and often can be managed nonoperatively.

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Ma OJ, Mateer JR, Kirkpatrick AW. Trauma. In: Ma OJ, Mateer JR, Reardon RF, Joing SA, eds. *Ma and Mateer's Emergency Ultrasound*. 3rd ed. New York: McGraw-Hill; 2014:61–92.

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Keywords/Tags: Nonoperative management

24. EXPLANATION

C. Inferior vena cava and aorta. The image shows the IVC as it courses through the liver, which can be mistaken for free fluid (Figure 1.32). The aorta is also visualized deeper on the image. The hepatic veins are seen as anechoic stripes within the liver that point in a diagonal direction, cephalad and medially toward the IVC. Other common RUQ false-positives include a fluid-filled gallbladder, renal cysts, and fluid-filled bowel. False-positive findings tend to show anechoic spaces that have round borders or are enclosed, whereas true free fluid tends to have sharp edges or irregular borders. When obtaining a RUQ FAST view, it is important to visualize the following regions: diaphragm, Morison's pouch, inferior pole of the kidney, and the inferior liver tip.

Learning Points: The IVC and aorta may mimic free fluid in the RUQ window of the FAST. The sonographer may fan the probe posteriorly to distinguish these anechoic stripes from free fluid.

FURTHER READING

Ma OJ, Mateer JR, Kirkpatrick AW. Trauma. In: Ma OJ, Mateer JR, Reardon RF, Joing SA, eds. *Ma and Mateer's Emergency Ultrasound*. 3rd ed. New York: McGraw-Hill; 2014:61–92.

Keywords/Tags: False-positives, inferior vena cava, aorta

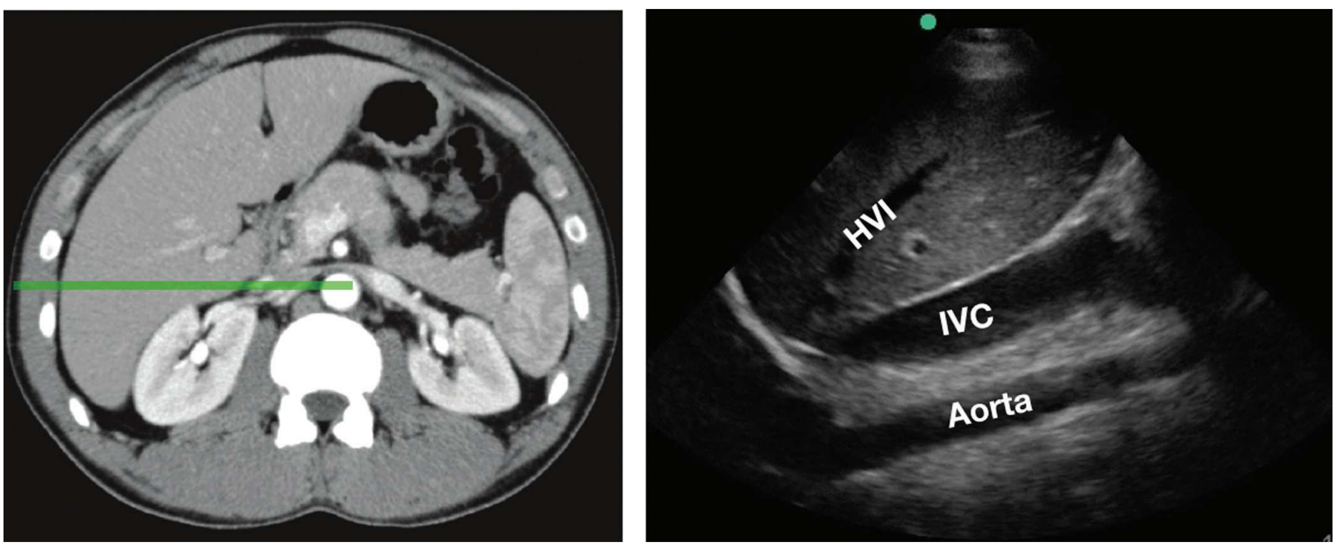

Figure 1.32 **Inferior vena cava (IVC) and aorta may mimic free fluid in the right upper quadrant window.** The axial CT image on the right shows the approximate scan plane that is captured. Notice that the hepatorenal space and right paracolic gutter are posterior and lateral to the IVC and aorta. Fanning and/or sliding the scan plane posteriorly will help to differentiate the IVC and aorta from free fluid in these spaces. Also, identifying the confluence of the hepatic vein inlet (HVI) with the IVC will confirm that the anechoic stripe is not free fluid but the IVC.

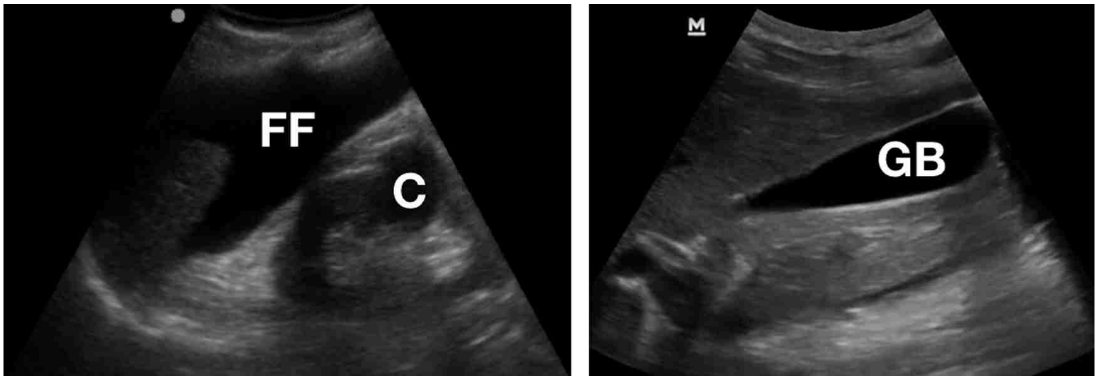

Figure 1.33 **Free fluid (FF) and a renal cyst (C) on the right upper quadrant window.** The liver tip is visualized surrounded by fluid, so the free fluid is seen both in the right paracolic gutter and hepatorenal space. On the image on the right, the gallbladder (gb) in long axis is seen. It is anterior to the right kidney, so upon identification, the sonographer should fan or tilt the probe posteriorly to visualize the hepatorenal space and right paracolic gutter.

25. EXPLANATION

D. A and B. The image shows free fluid as well as a renal cyst (Figure 1.33). The free fluid is in the hepatorenal space while the renal cyst appears globular and well circumscribed. Neither the IVC nor the aorta is seen in this plane. Other common RUQ false-positives include a fluid-filled gallbladder and fluid-filled bowel. False-positive findings tend to show anechoic spaces that have round borders or are enclosed, whereas true free fluid tends to have sharp edges or irregular borders.

Learning Points: A prominent gallbladder or renal cyst may mimic free fluid in the RUQ window of the FAST. Note that the gallbladder in long axis often forms an "exclamation sign" with the portal vein. The sonographer may fan the probe posteriorly to find the hepatorenal space as well as distinguish the circular appearance of cysts from angular or irregular borders of free fluid.

FURTHER READING

Ma OJ, Mateer JR, Kirkpatrick AW. Trauma. In: Ma OJ, Mateer JR, Reardon RF, Joing SA, eds. *Ma and Mateer's Emergency Ultrasound*. 3rd ed. New York: McGraw-Hill; 2014:61–92.

Keywords/Tags: False-positives, gallbladder, renal cyst

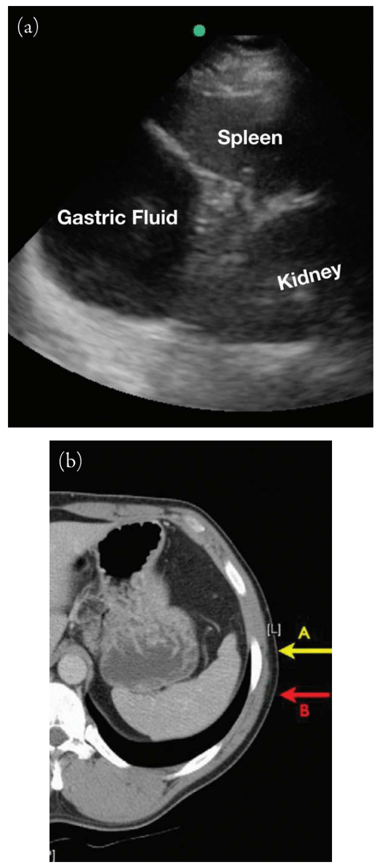

Figure 1.34 (a) **Gastric fluid visualized on left upper quadrant window.** The lateral spleen is often visualized followed by the posterior portion of the stomach. Normally stomach air will create a hazy "dirty shadowing" that prevents visualization of any structures medial to it. However, with a fluid-filled stomach, a cystic anechoic space is visualized that can be mistaken for free fluid. (b) **This axial CT shows the relationship of the spleen to the stomach and how the gastric fluid sign or stomach sabotage occurs.** In the "A" plane, the lateral spleen is visualized but not the more posterior medial spleen. In the more posterior "B" plane, the medial spleen is visualized because the stomach lies just anterior to the medial spleen. Adapted from Figure 4 of Nagdev A, Racht J. The "gastric fluid" sign an unrecognized false-positive finding during focused assessment for trauma examinations. *Am J Emerg Med.* 2008;26(5):630.e5–7.

26. EXPLANATION

B. The fluid present is within the stomach. When examining a LUQ view, fluid in the stomach can be mistaken for free intraperitoneal fluid. This is often referred to as the "gastric fluid sign" or "stomach sabotage." Other common LUQ false-positives include fluid-filled bowel, IVC, and aorta. To optimize the LUQ view, the transducer should be placed at the left posterior axillary line (often referred to as "knuckles to the bed") between the 8th and 11th ribs. To differentiate between the presence of free peritoneal fluid and fluid within the

stomach, tilt the face of the probe posteriorly along the posterior axillary line so that the sound waves are pointing posterior to the stomach. The fluid within the stomach will disappear, and the medial part of the spleen will be visualized without free fluid in the subphrenic or splenorenal space (Figure 1.34).

FURTHER READING

Ma OJ, Mateer JR, Kirkpatrick AW. Trauma. In: Ma OJ, Mateer JR, Reardon RF, Joing SA, eds. *Ma and Mateer's Emergency Ultrasound*. 3rd ed. New York: McGraw-Hill; 2014:61–92.

Nagdev A, Racht J. The "gastric fluid" sign an unrecognized false-positive finding during focused assessment for trauma examinations. *Am J Emerg Med*. 2008;26(5):630.e5–7.

Keywords/Tags: LUQ, false-positives

27. EXPLANATION

C. Epicardial fat pad. An epicardial (sometimes referred to as pericardial) fat pad can mimic a pericardial effusion. Fat is usually hypoechoic/anechoic in the middle and surrounded by a thin hyperechoic border. Epicardial and paracardial fat are usually present, but epicardial fat is supplied by the coronary arteries, whereas paracardial fat is supplied by thoracic arteries. On echocardiography, it is difficult to differentiate the 2 layers. However, epicardial fat lies between the visceral pericardium and myocardium, while paracardial fat lies external to the fibrous pericardium. Both are relatively anechoic, but epicardial fat can be echogenic if thickened (>15 millimeters). In addition, epicardial fat deforms or moves with the cardiac cycle, while paracardial fat usually does not. Both fat pads can be distinguished from simple pericardial effusions as they are usually located anterior to the right ventricle and not seen posterior to the left ventricle. Pericardial effusions are typically anechoic and usually gravity dependent and thus are seen first along the posterior pericardium and then along the anterior pericardium with increasing size (Figure 1.35).

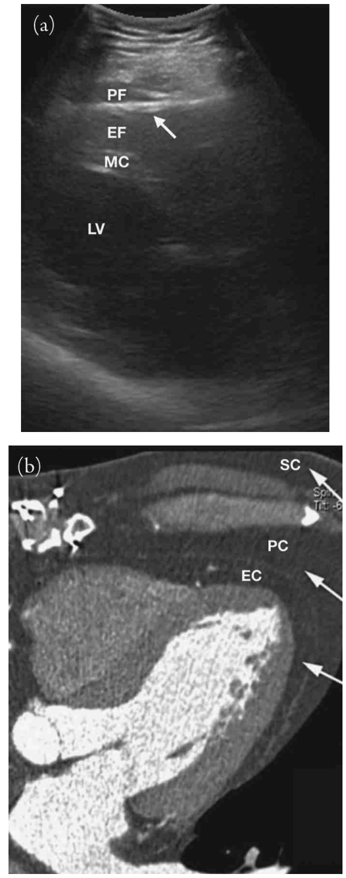

Figure 1.35 (a) **Epicardial fat pad on parasternal long axis.** In this high parasternal long axis view, the epicardial fat (EF) lies between the myocardium (MC) and the visceral pericardium (arrow). The paracardial fat pad (PF) lies external to the fibrous pericardium. In this view, the left ventricle (LV) is seen but the right ventricle is not clearly seen. (b) **The relationship between epicardial, pericardial or paracardial fat, and subcutaneous fat.** This thoracic CT section shows that epicardial fat lies between the myocardium and visceral pericardium, while pericardial or paracardial fat lies external to the fibrous pericardium. Adapted from Figure 21 of Cosyns B, Plein S, Nihoyanopoulos P, et al. European Association of Cardiovascular Imaging (EACVI) position paper: multimodality imaging in pericardial disease. *Eur Heart J Cardiovasc Imaging*. 2015;16(1):12–31.

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Keywords/Tags: False-positives, subxiphoid, pericardial fat pad

28. EXPLANATION

B. Perinephric fat without free abdominal fluid. The image shows a "double line sign," a commonly seen false-positive finding caused by perinephric fat. The "double line sign" is a hypoechoic region in Morison's pouch surrounded on both sides by echogenic borders due to fascial planes. Perinephric fat can mimic free fluid or hematoma. Free fluid will be external to the hyperechoic borders of perinephric fat (Figure 1.36). Hepatic veins will appear within the liver parenchyma and have relatively anechoic walls. Fluid-filled bowel will outline the round bowel walls and typically exhibit peristalsis.

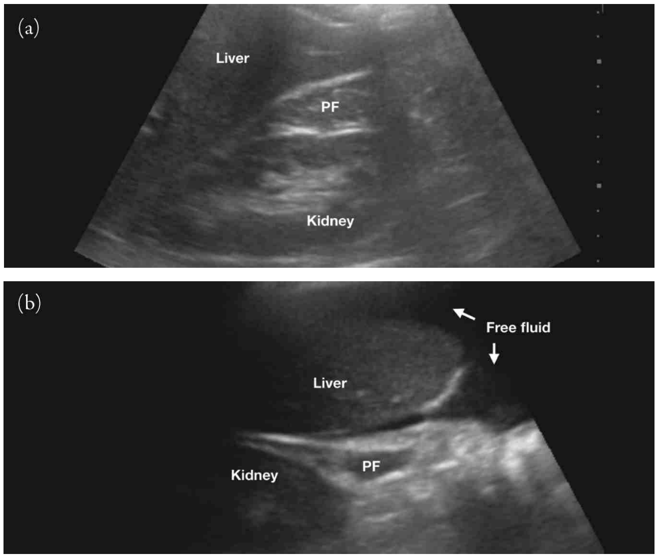

Figure 1.36 (a) **Perinephric fat.** The perinephric fat is contained within the fascial planes of the kidney, which are seen as bright hyperechoic lines. The fat when thin (<5 mm) is relatively more hyperechoic than when the fat layer is thick (>10 mm). (b) **Perinephric fat with free fluid.** Free fluid will be external to the kidney's fascial planes, as seen in this image. The perinephric fat (PF) is contained within the fascial planes.

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Keywords/Tags: "Double line sign," perinephric fat, false-positives

29. EXPLANATION

D. Tension pneumothorax. The lung ultrasound shows no lung sliding and M-mode shows a "barcode or stratosphere" sign, which is indicative of a pneumothorax on the right. On M-mode, normal lung sliding will appear similar to "waves on a beach" or a "seashore." This is seen on the left lung. The very echogenic horizontal line on M-mode corresponds to the visceral–parietal pleural interface (VPPI). There is pleural sliding in normal lung, thus the M-mode tracing deep to the VPPI appears granular, while the relatively still structures superficial to the VPPI appear as contiguous horizontal lines. A pneumothorax will look like a "barcode or stratosphere," since the VPPI shows no sliding or movement. There is no evidence of cardiac tamponade or AAA.

The EFAST is an ultrasound protocol that involves the evaluation of the lung pleura for the presence of pneumothorax in addition to what is evaluated in the FAST exam. In this case, it helped to rapidly confirm the etiology of the patient's presentation, without delays associated with other imaging modalities.

Learning Points: M-mode can be used to assess for a pneumothorax. Normal pleural sliding will appear similar to "waves on a beach" or a "seashore." A pneumothorax will look like a "barcode."

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Keywords/Tags: "barcode sign," M-mode, pneumothorax, RUSH protocol

30. EXPLANATION

C. Pleural effusion. Pleural effusion tracks lateral or deep to the aorta in the parasternal long axis view on ultrasound whereas a pericardial effusion tracks anterior to the aorta. On diaphragm views of the EFAST, pleural effusions will be seen as extensions of the vertebral column superior to the diaphragm. This is known as the "spine sign," which is more sensitive and specific for pleural effusions than chest radiographs. Patients with lung consolidation such as pneumonia will have characteristic findings on ultrasound such as hepatization, sonographic bronchograms, and/or B-lines. In normal lung, a point of care ultrasound will be echogenic and difficult to visualize due to artifact from the presence of air. In the presence of pneumonia, the lung appears organ-like, similar to the appearance of the liver (hence the term *hepatization*). This is often accompanied by air bronchograms, which are hyperechoic lines and dots within a hypoechoic area, which represents air that is trapped in airways where there is a consolidation.

A normal lung ultrasound without the presence of extravascular lung edema will show hyperechoic, repetitive lines that are equidistant from one another (i.e., A-lines) from the top to the bottom of the screen, indicating that the lung is dry.

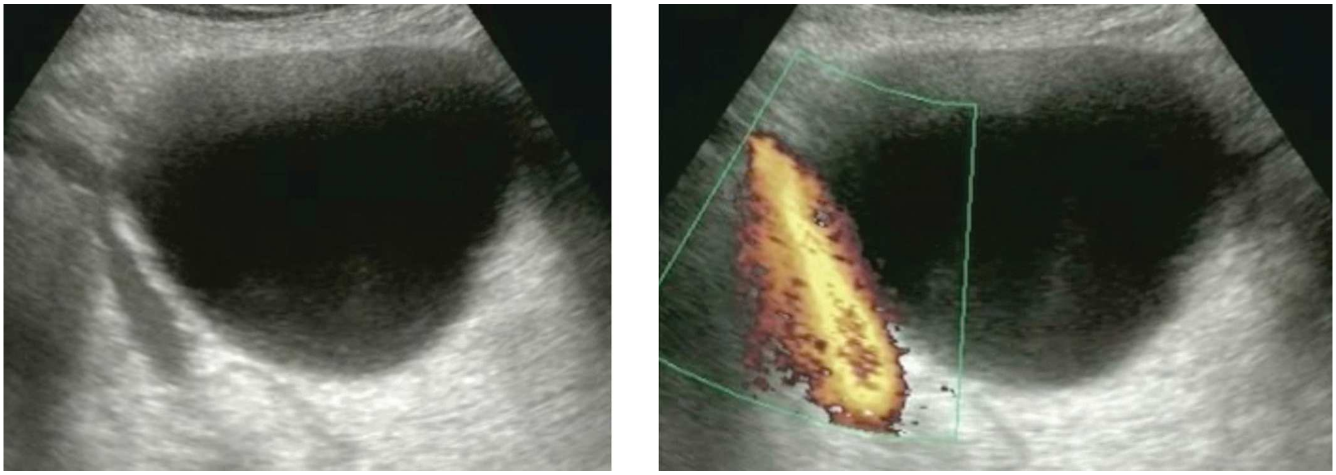

Figure 1.37 **Identifying iliac vessels using color Doppler.** The image on the left shows the vessels without color, while the image on the right shows flow on color power Doppler (CPD), confirming that the fluid is intraluminal and not pelvic free fluid.

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Keyword/Tags: Pleural effusion

31. EXPLANATION

D. Use color Doppler. There is a large anechoic strip lateral to her bladder that can be free fluid. However, there is no fluid posterior to the bladder. Using color Doppler allows for differentiation of vascular structures from free fluid (Figure 1.37). In this case, there is ample flow on color power Doppler, confirming that the right common iliac vein is identified. Blood product replacement and emergent surgical exploration is indicated for ruptured ectopic pregnancy, but the clinical evaluation does not indicate this currently. A transvaginal pelvic ultrasound may be indicated if a sweep of the uterus does not identify a definitive intrauterine pregnancy on transabdominal pelvic ultrasound.

Learning Points: Color Doppler may be used to identify and distinguish vascular structures from free fluid.

FURTHER READING

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All figures and tables provided in this chapter are courtesy of Alan Chiem, MD.

2.

FOCUSED ECHOCARDIOGRAPHY

Connie Yu, Rachel Liu, Vi Am Dinh, and Alan T. Chiem

QUESTIONS

1. The local ambulance group brings you a 65-year-old male complaining of worsening shortness of breath for 2 hours. He was performing yard work when his symptoms started and has never had these symptoms previously. One year ago, he underwent cardiac catheterization for obstructive coronary artery disease and had an unremarkable echocardiogram except for some valvular heart disease.

You ultimately perform a focused bedside echocardiogram to assess the etiology of his symptoms and want to assess his ejection fraction using the EPSS method. What can falsely affect the EPSS measurement demonstrated in the image (Figure 2.1, Video 2.1)?

A. Prior history of percutaneous coronary intervention
B. Artificial valve
C. Pulmonary hypertension (pHTN)
D. Diastolic dysfunction

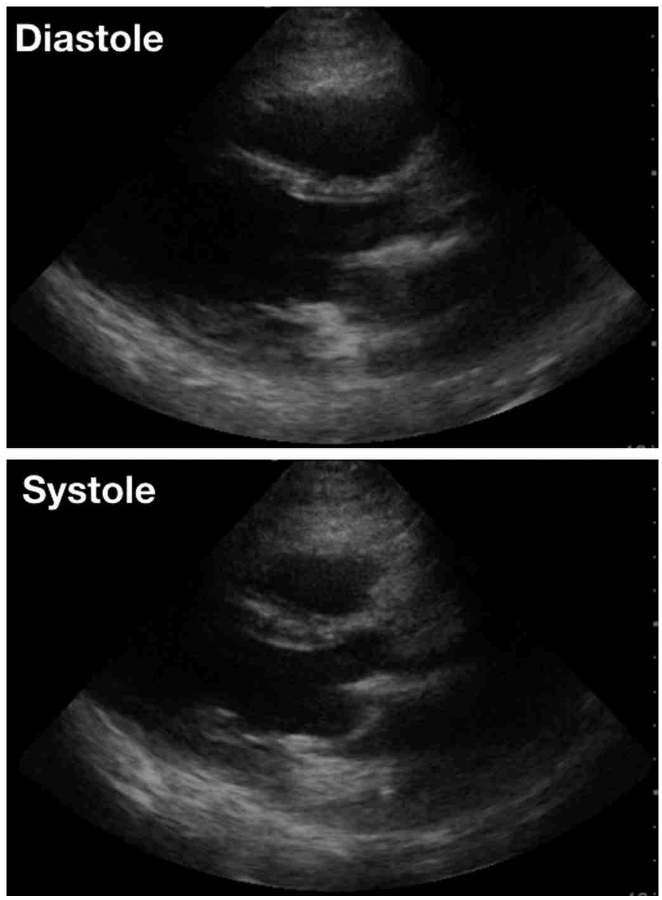

Figure 2.1

2. A 48-year-old male with history of end-stage renal disease, coronary artery disease, and cardiomyopathy presents with productive cough and shortness of breath. As you perform your assessment, he is unable to lie supine without experiencing mild respiratory distress. You perform limited echocardiography. Based on your findings in the image (Figure 2.2, Video 2.2), what is your diagnosis?

A. Pericardial effusion
B. Pleural effusion
C. Pneumonia
D. Both A and B

3. A 50-year-old female with history of end-stage renal disease and lupus presents with altered mental status and fever. She missed the last two sessions of her dialysis. Vital signs are notable for a temperature (T) 101.2, blood pressure (BP) 95/60, heart rate (HR) 125, respiratory rate (RR) 24, oxygen saturation SpO_2 94% on 2 liters per nasal cannula. As part of your assessment of the undifferentiated shock patient, you perform point-of-care echocardiography (Figure 2.3, Video 2.3).

Figure 2.2

What is the view obtained and how do you quantify this finding?

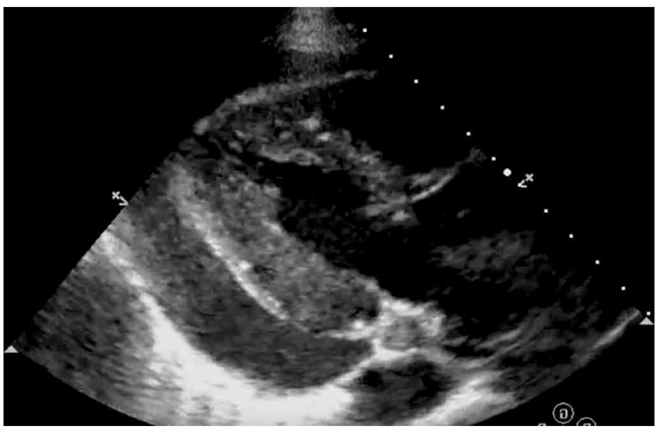

Figure 2.3

A. Subxiphoid view, in systolic phase along anterior pericardium
B. Subxiphoid view, in diastolic phase along anterior pericardium
C. Parasternal long axis view, in systolic phase along posterior pericardium
D. Parasternal long axis view, in diastolic phase along posterior pericardium

4. To help determine the etiology of an acutely dyspneic patient, you obtain a parasternal long axis view on your bedside echocardiogram. You decide to obtain an EPSS. What is true about the EPSS?

A. The M-mode line should be perpendicular to the IVS.
B. The M-mode line should intersect the tip of the anterior mitral valve leaflet.
C. The parasternal long axis plane should be at the center of the LV chamber.
D. All of the above

5. An 80-year-old male from a nursing home presents with altered mental status. On exam, he is in mild distress secondary to difficulty breathing. Mucus membranes are dry, capillary refill >3 seconds. Lung sounds are coarse bilaterally with crackles. A soft holosystolic murmur is present. Abdomen is soft and nontender. Vital signs are notable for T 102°F, BP 80/50, HR 120, RR 30 and SpO_2 92% on nasal cannula. Based on the point-of-care ultrasound (POCUS) performed (Figure 2.4, Video 2.4), what kind of shock is he most likely exhibiting?

A. Septic shock
B. Cardiogenic shock
C. Neurogenic shock
D. Obstructive shock

6. You encounter a patient with progressively worsening shortness of breath, who also happens to have chronic obstructive pulmonary disease and has never been to your hospital. Which of the following is *not* a reliable method to differentiate new from chronic pulmonary hypertension (pHTN) on your echocardiographic assessment?

A. Measurement of the RV free wall
B. Global assessment for chamber size
C. Measurement of the pressure gradient between the right atrium and RV
D. Assessment of RA size

7. A 48-year-old female comes to the emergency department for acute dyspnea. She recently returned from a family vacation in New Zealand about 2 days ago when she noticed her legs aching. History is otherwise unremarkable. She is placed on oxygen as you perform a cardiopulmonary examination and subsequently a bedside echocardiogram (Figure 2.5).

In the video clip (Video 2.5), this finding is a reliable indicator for which of the following clinical conditions?

A. Myocardial infarction
B. Sarcoidosis
C. Acute pulmonary embolism
D. None of the above

8. A 30-year-old female with a history of substance abuse presents with fevers and chills for 2 days. She has also noticed shortness of breath with walking up the stairs and coughing up blood tinged sputum. Your focused physical examination reveals a female who appears tired with multiple track marks on her arms. No jugular vein

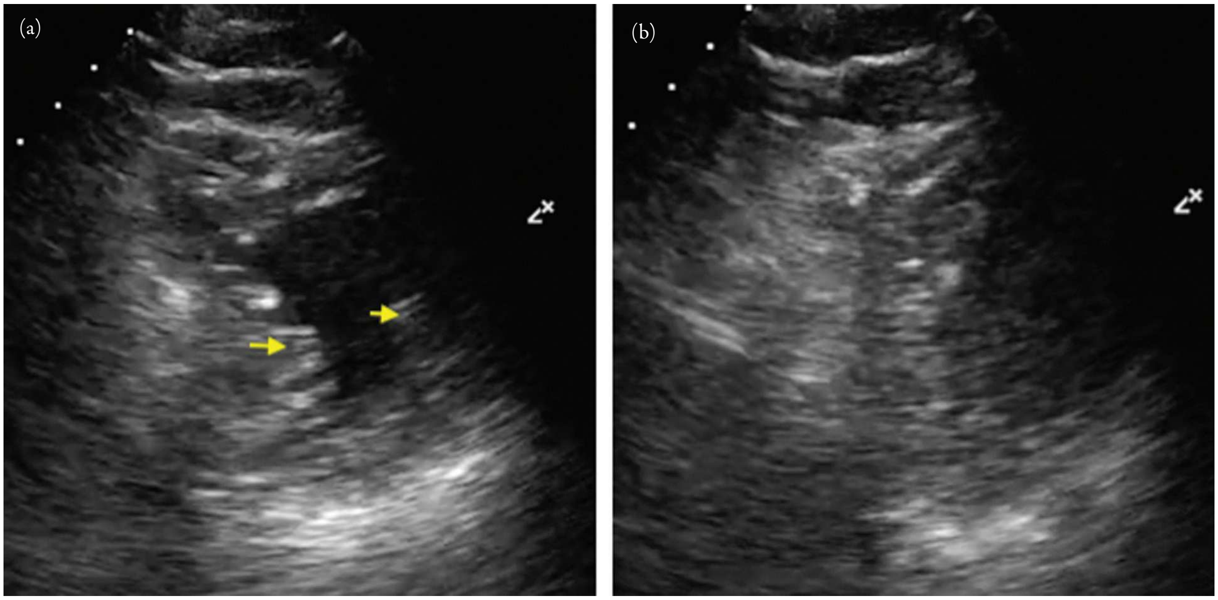

Figure 2.4 **Parasternal short axis at mid apex, at end diastole (a) and end systole (b).**

distention (JVD) is present, lungs are clear, and a grade 2/6 holosystolic murmur is appreciated along the sternal border. Based on your exam and echocardiography (Figure 2.6, Video 2.6), what is the most likely culprit for her symptoms?

A. Patent foramen ovale (PFO)
B. Ventricular septal defect
C. Aortic regurgitation
D. Tricuspid regurgitation

9. A 56-year-old female with history of end-stage renal disease on dialysis, hypertension, diabetes, and CREST syndrome presents with weakness. Vital signs are notable for T 38.3°C, BP 95/60, HR 115, RR 24, SpO_2 94% on nasal cannula. Physical exam is notable for an ill-appearing female with dry mucous membranes, bibasilar crackles, obese abdomen, and pretibial edema, with cap refill >2 seconds. You perform a bedside echocardiogram, which is notable for what clinical finding (Figure 2.7, Video 2.7)?

A. McConnell's sign
B. Carvallo's sign
C. Ventricular interdependence
D. Focal wall motion abnormality

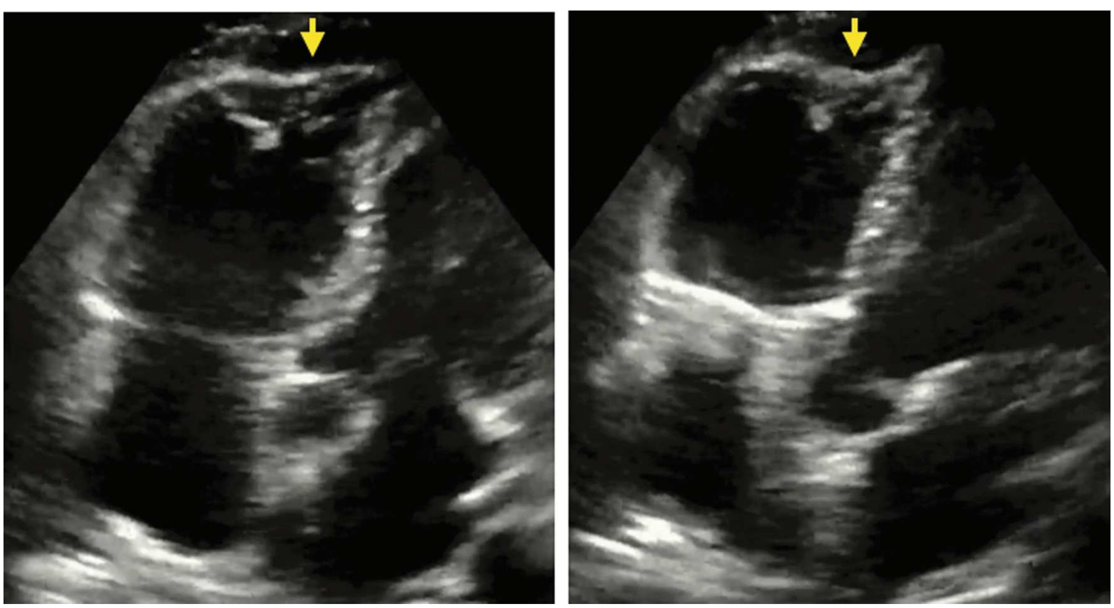

Figure 2.5 **Apical five chamber window with arrow pointing to RV apex at diastole (L) and systole (R).**

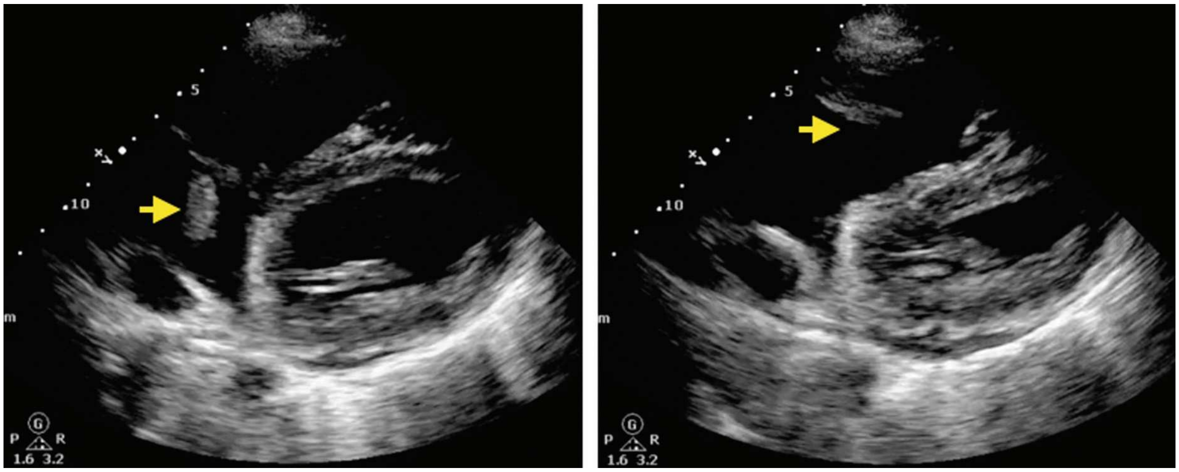

Figure 2.6

10. Based on the image in Figure 2.8, the probe indicator is directed toward what part of the body?

A. Right shoulder
B. Right hip
C. Left shoulder
D. Left hip

11. During your first overnight shift, you encounter an 88-year-old male in the resuscitation room. He woke up early in the morning with "difficulty breathing." His vital signs are notable for temperature 37.8°C, BP 198/95, HR 112, RR 32, and SpO_2 86%. He appears moderately distressed, sitting upright and diaphoretic. He exhibits bilateral crackles, JVD but minimal pedal edema; abdomen is protuberant and nontender. His medical history is only notable for hypertension, hyperlipidemia, and diabetes mellitus. Bedside ultrasound reveals normal LV systolic function on visual estimation. What modality can you perform as a next step in assessing the etiology of this patient's decompensation?

A. CWD
B. PWD
C. Tissue Doppler imaging (TDI)
D. B and C

12. A 62-year-old male presents with "trouble breathing" for the past week. He ran out of his medications two weeks ago. Since then he has had increasing dyspnea, orthopnea, and swelling. Vital signs are notable for normal temperature, BP 160/100, HR 105, RR 25, and SpO_2 90% on room air. There is notable JVD, bibasilar crackles and S3 gallop, soft nontender abdomen and moist, and 2+ edema to lower extremities. EKG performed at triage shows a LVH pattern but no ischemia.

You perform a bedside echo that shows normal LVEF, no pericardial effusion, or RV strain. Additional advanced echocardiographic maneuvers are performed

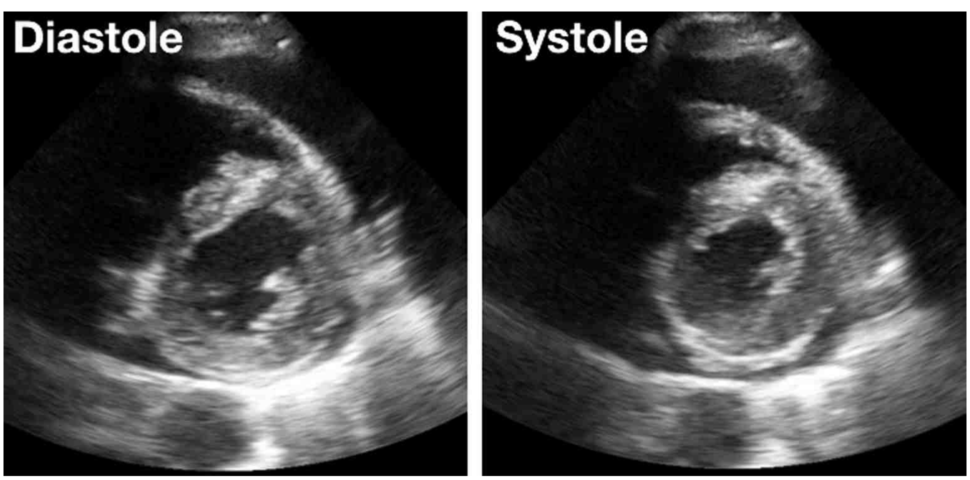

Figure 2.7

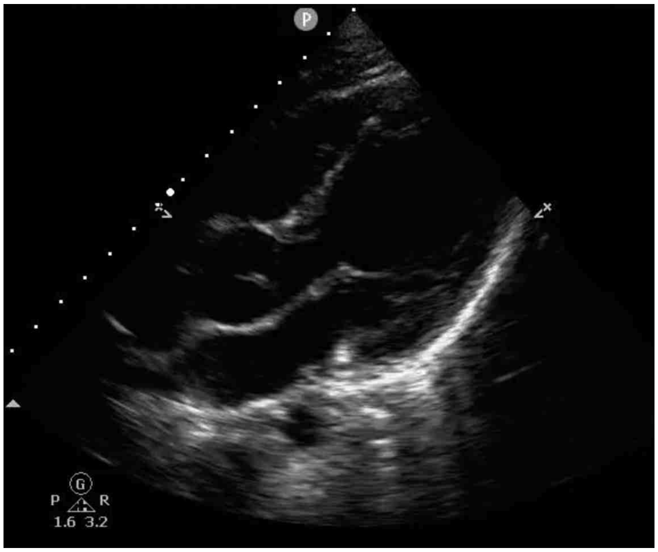

Figure 2.8

assessing for compliance and ventricular function. Based on the images (Figure 2.9), what type of diastolic dysfunction is present?

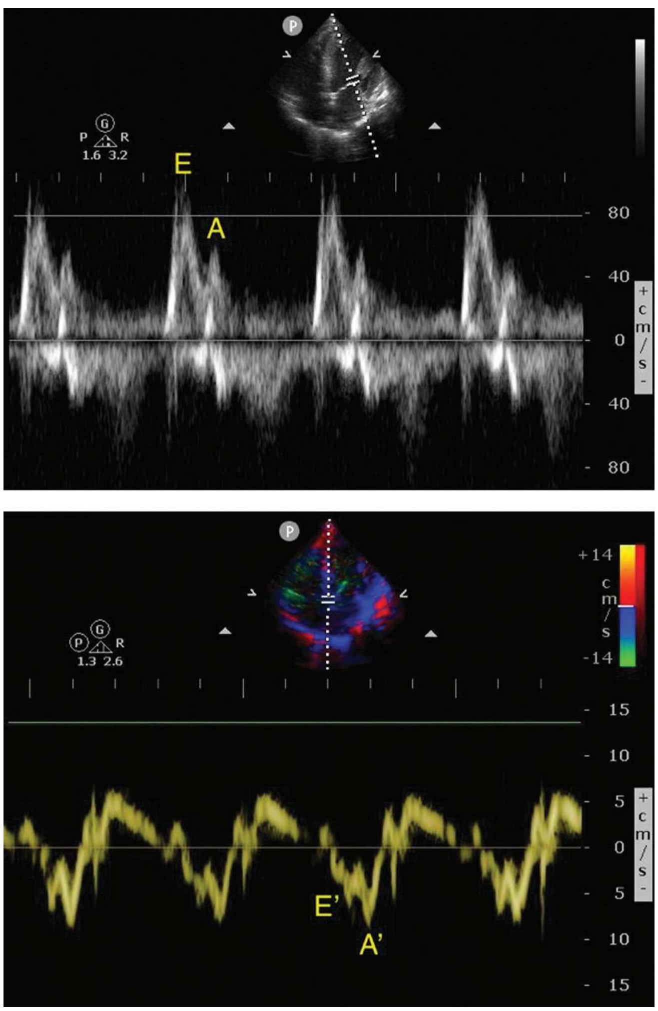

Figure 2.9

A. Normal
B. Grade 1
C. Grade 2
D. Grade 3

13. A 32-year-old male with history of cocaine abuse presents to the emergency department with substernal chest pain radiating to his left arm. He uses cocaine occasionally, but not preceding his symptoms. He denies other drug use, medical, or family history.

His vital signs are as noted: temperature 36.5°C, BP 165/96, HR 82, and SpO_2 100% on room air. He is anxious and mildly diaphoretic, but otherwise is in no acute distress. Neck is supple without JVD or carotid bruit. Lungs are clear, and no murmurs are appreciated. Abdomen is soft, nontender. There is no peripheral edema and pulses are 2+ throughout.

A cardiac workup is initiated and pending. Aspirin is administered and an EKG is obtained as shown (Figure 2.10). On this parasternal short axis window, you see a hypokinetic area of the LV wall (Figure 2.11, arrow). What coronary artery supplies this region?

A. Left anterior descending artery (LAD)
B. Left circumflex artery (LCx)
C. Right coronary artery (RCA)
D. Posterior descending artery (PDA)

14. A 55-year-old female presents with weakness, abdominal cramping, and watery diarrhea for 3 days. She was treated for urinary tract infection 3 weeks ago. There is no significant medical or surgical history except for a Caesarean section. Her medications include calcium, vitamin D, and aspirin daily.

Vital signs are notable for T 100.6°F, BP 85/60, HR 125, RR 20, and SpO_2 95% on room air. There is mild distress and colicky appearance. Mucus membranes are dry, neck supple, and no oral lesions. Lungs clear, rapid and regular rhythm, and abdomen protuberant and tympanic, diffusely tender with voluntary guarding. Skin moist and warm throughout, cap refill = 2 seconds.

You perform components of the RUSH exam and obtain the images displayed in Figure 2.12 and Videos 2.9 and 2.10.

All of the following are immediate next steps in management *except*:

A. Norepinephrine drip.
B. Intravenous broad spectrum antibiotics.
C. Fluid resuscitation 30 cc/kg bolus.
D. Acetaminophen.

15. You attempt a parasternal short-axis window. What structure is not visualized in this image (Figure 2.13, Video 2.11)?

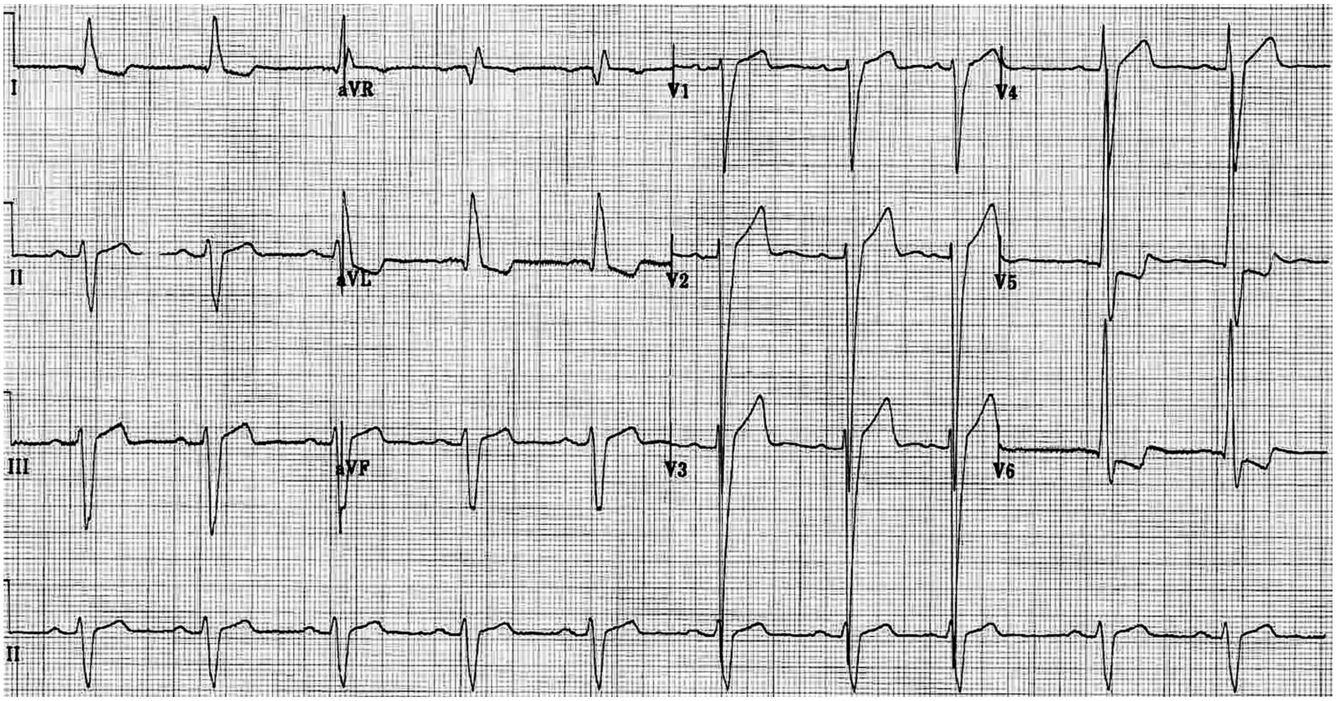

Figure 2.10

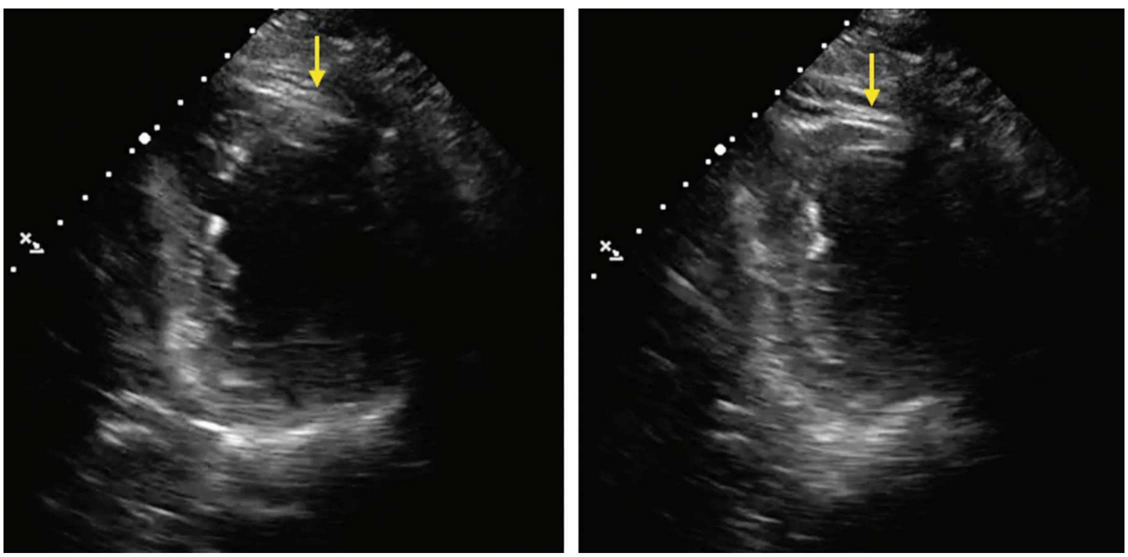

Figure 2.11

A. Aortic valve
B. Tricuspid valve
C. Pulmonic valve
D. Mitral valve

16. A 35-year-old male presents to your emergency department with pleuritic chest pain and generalized fatigue. He has had upper respiratory tract infection (URI) symptoms for the past 2 weeks, but his pleuritic chest pain, which he thought was due to his cough, has started to worsen. He appears tired, with T 99.2°F, BP 106/78, HR 116, RR 22, and SpO_2 95% on room air. He has mild JVD, clear lung sounds without stridor and a tachycardic S1S2 without peripheral edema. His EKG shows sinus tachycardia with low voltage.

You obtain a POCUS study (Figure 2.14, Video 2.12) and are concerned about cardiac tamponade. What is the most sensitive finding of cardiac tamponade?

A. Right atrial systolic collapse
B. RV diastolic collapse
C. LV diastolic collapse
D. Left atrial systole collapse

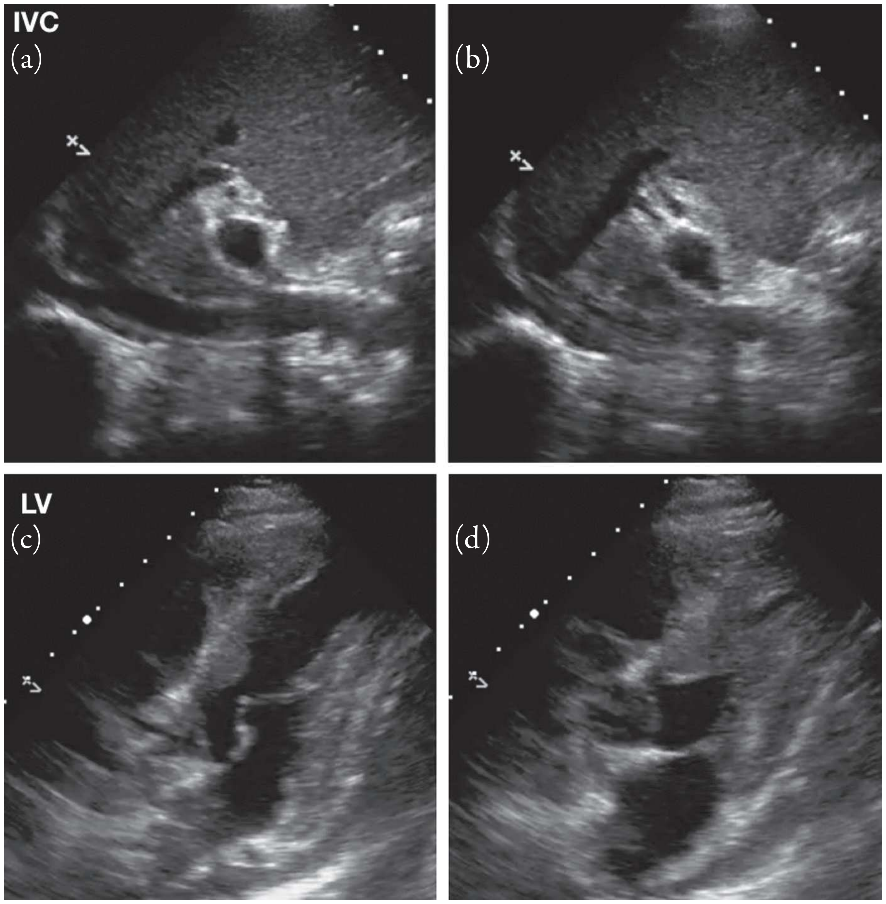

Figure 2.12 Inferior vena cava respiratory variability (a, b); apical five chamber window during diastole and systole (c, d).

17. A 67-year-old female with a history of diabetes presents with left-sided weakness for the past 2 days. She has also had a fever and malaise for about 1 week. Her initial vital signs include T 38.5°C, BP 102/80, HR 115, RR 24, and SpO_2 93% on room air. She has bibasilar rales and a 3/6 holosystolic murmur best over the apex. She has a subtle facial droop and 4/5 arm weakness and numbness on the left. She has no tender nodes or rash.

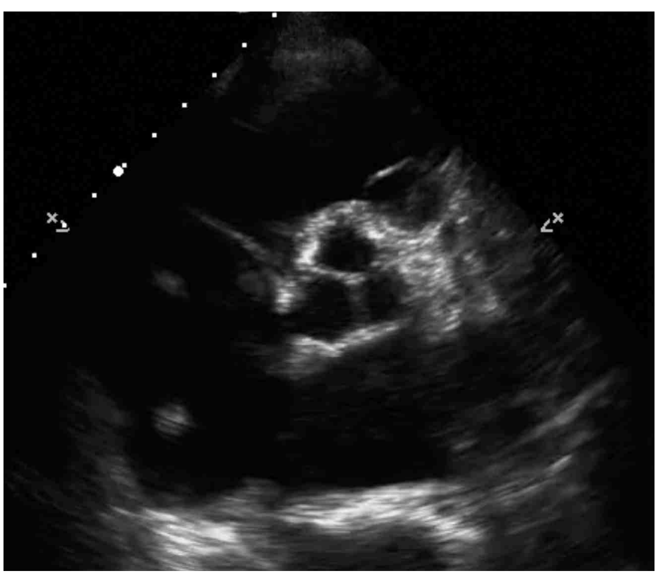

Figure 2.13

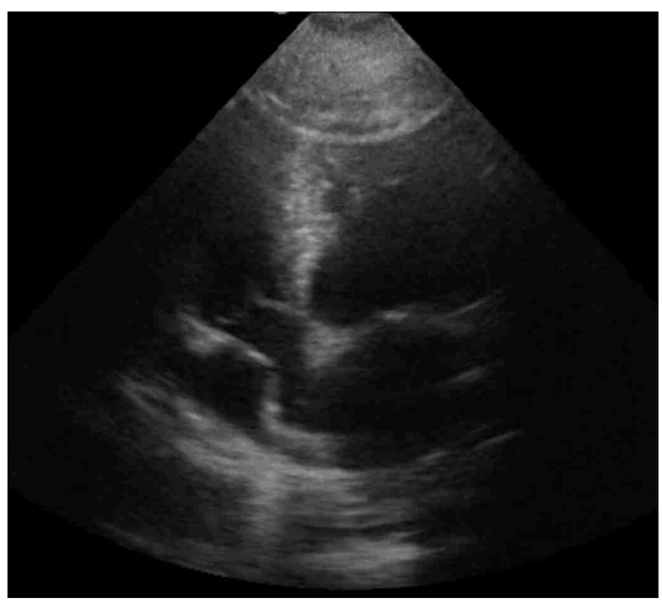

Figure 2.14

Given your concerns, you perform a bedside ultrasound to narrow your differential diagnosis for this patient and expedite her care (Figure 2.15, Video 2.13). What is the likely diagnosis?

A. Aortic stenosis
B. Mitral stenosis
C. Aortic regurgitation
D. Mitral regurgitation

18. A 68-year-old African American female with history of hypertension and diabetes presents with progressive shortness of breath over the past 2 weeks. She denies cough or congestion, fevers or chest pain. Vital signs are notable for T 98.8°F, BP 135/87, HR 85, and SpO_2 94% on room air. She is in no acute distress. She has mild JVD, bibasilar crackles, and a rumbling diastolic murmur with opening snap, and 2+ pitting edema bilaterally. You perform a POCUS echo. What is the most likely etiology for the finding in Figure 2.16 and Video 2.14?

A. Severely depressed LV systolic function
B. Pulmonary embolism
C. Mitral regurgitation
D. Mitral stenosis

19. A 50-year-old male with no known medical history collapses while exercising at the fitness center. An EMS crew arrives to find a pale and diaphoretic male on the ground. He is placed on a cardiac monitor, which shows sinus tachycardia. He is promptly transferred to the local emergency department to your care.

You encounter the patient who appears as EMS described, in the resuscitation bay. You establish IV access and place the patient on the monitor and additionally communicate to your nursing staff that you are ordering a basic cardiac panel, EKG, and chest X-ray. You then perform a POCUS (Figure 2.17) and obtain the video clip shown in Video 2.15. What should be present on your physical examination?

A. Holosystolic murmur
B. Mid-systolic click
C. Mid-diastolic rumble
D. Systolic crescendo decrescendo murmur

20. A 52-year-old morbidly obese female presents with new symptoms of congestive heart failure for the past week. She appears fluid-overloaded with lower extremity edema, but it is difficult to appreciate JVD nor assess lung or heart sounds due to her body habitus. You attempt a parasternal long axis, but get a very limited window. Her systolic function appears diminished, but you are not able to reliably distinguish her endocardial border. Assuming you have access, what type of echo contrast would help you?

A. Have patient Valsalva with agitated saline
B. Inject about 10 ml of normal saline
C. Use a high molecular weight contrast with diameter of 20μM
D. Use a high molecular weight contrast with diameter of 5μM

21. You have obtained a parasternal long axis image and can visualize the descending aorta (Figure 2.18, Video 2.16). There is no pericardial effusion present, but you see something "moving" distal to the descending aorta.

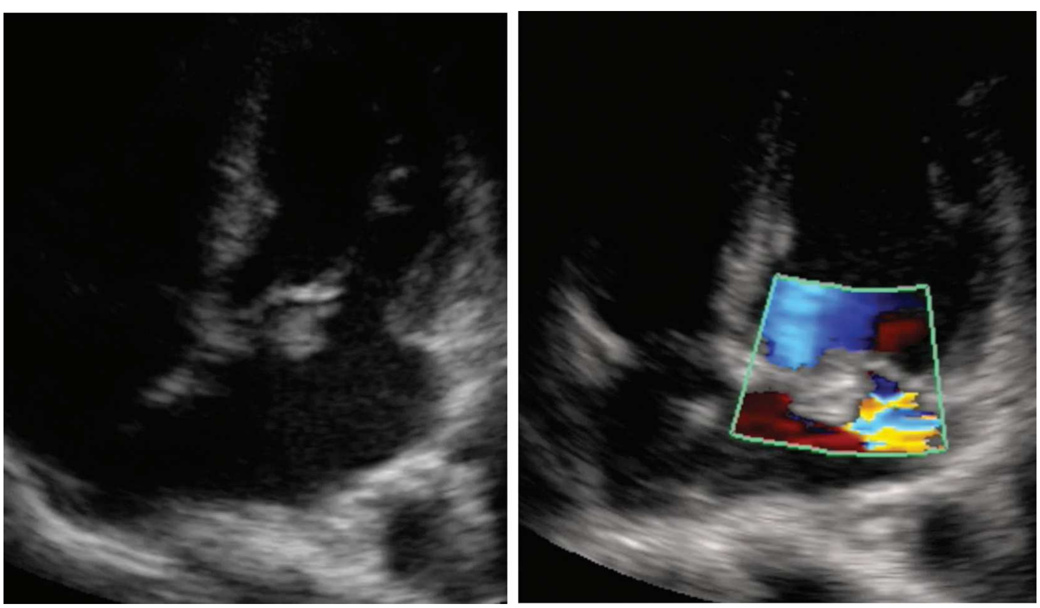

Figure 2.15

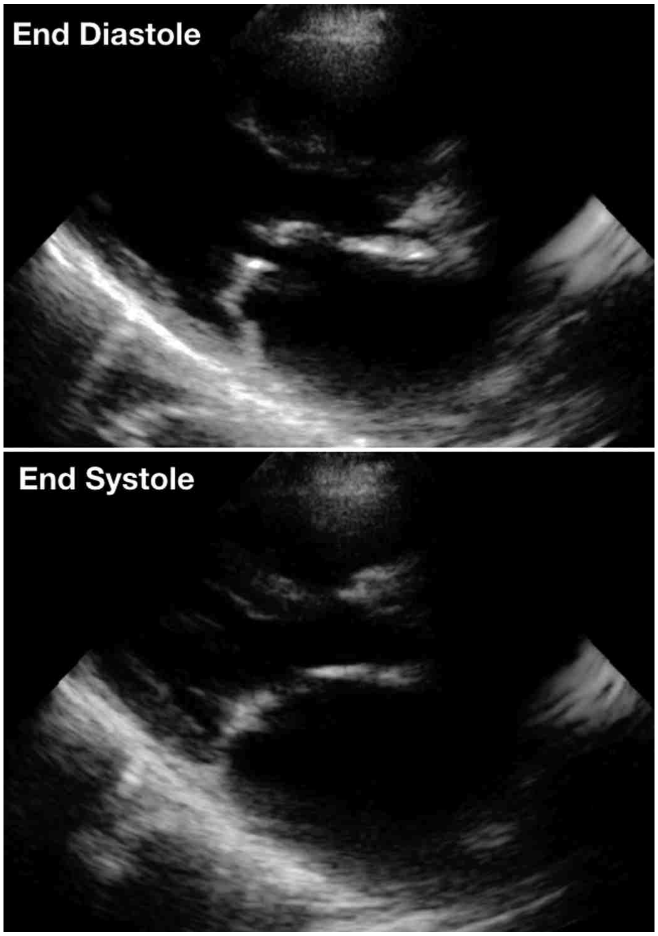

Figure 2.16

Identify the artifact that creates the appearance of movement in the far field:

A. Refraction artifact
B. Posterior acoustic enhancement
C. Edge artifact
D. Mirror artifact

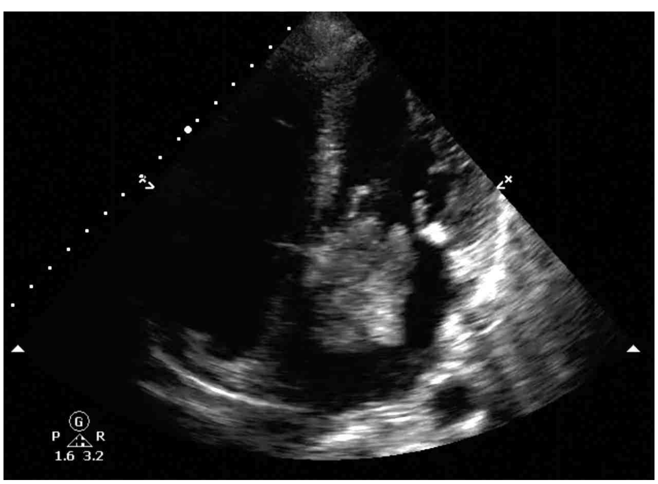

Figure 2.17

22. A 58-year-old male presents with increasing shortness of breath. On examination, a holosystolic murmur is found at the left lower sternal border that the patient was previously unaware of. It seems to increase with inspiration. You attempt to assess his valves using an A4C view, but because of his habitus, the view is difficult to obtain. You suspect RV enlargement based on your limited view. What other view could you use to evaluate his suspected condition and valvulopathy?

A. Parasternal short axis at the level of the aortic valve
B. Apical 3-chamber (A3C) view to evaluate aortic and mitral valves
C. RV tricuspid tilt view to evaluate the tricuspid valve
D. A and C

23. A 46-year-old male presents with acute crushing chest pain. You perform a parasternal short axis view that suggests subtle anterior wall motion abnormality. You wish to confirm this finding using another view. Which view will you obtain?

A. Parasternal long axis view
B. Subxiphoid View
C. A2C view
D. A5C view

24. A 46-year-old female presents with pleuritic chest pain, nasal congestion, and productive cough for 4 days. She looks tired, but she is mentating well and has clear lung sounds with a tachycardic S1S2. Her EKG shows sinus tachycardia to 105 bpm and diffuse PR depressions. You decide to evaluate for evidence of pericardial effusion or depressed LV function from myopericarditis. She has no obvious pericardial effusion, but you are not confident in your ability to assess normal from abnormal systolic function by "eyeballing" and decide you need a volumetric method for estimating ejection fraction.

Which of the following statements is *false*?

A. Simpson's biplane method sums up the volume of 20 discs, which makes less assumptions of LV geometry than comparable methods.
B. The area-plane approach assumes a "bullet-shaped" LV.
C. The Teichholz method assumes that the LV length is twice the diameter of the base.
D. EPSS and FS are more accurate than volumetric methods of ejection fraction estimation.

25. A 38-year-old male being treated for lymphoma presents with some mild dyspnea for the past week. He has had a sore throat, rhinorrhea, and mild productive cough for the same duration. He looks well, with a normal cardiopulmonary exam, RR of 18 and O_2 sat of 100% on room air. He brings a printed report from an outside

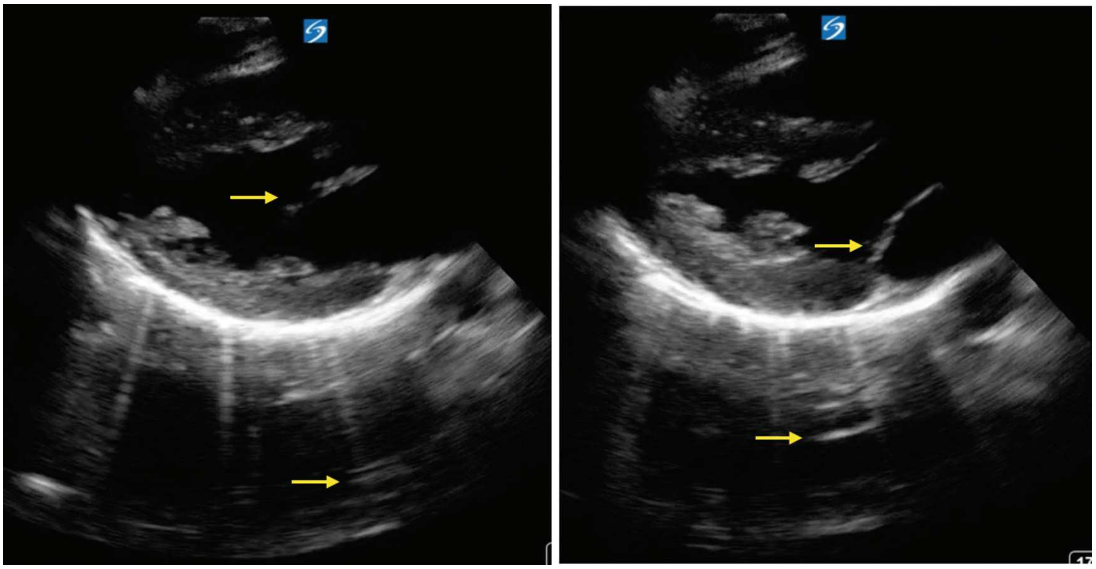

Figure 2.18

cardiologist of his "heart ultrasound" and is concerned by the image (Figure 2.19). He does not remember why the study was performed.

What do you tell him?

A. There is evidence of systolic dysfunction.
B. There is evidence of diastolic dysfunction.
C. There is regional dysfunction.
D. There is no evidence of abnormalities.

26. An 88-year-old male with a history of heart failure with preserved ejection fraction (HFpEF) and AFib presents with worsening dyspnea and orthopnea for the past three days. He also endorses URI symptoms in that time period. On exam, he appears mildly dyspneic, with no appreciable JVD, some bibasilar rales, and no discernable gallops or rubs with his irregularly irregular rhythm. His legs have 1+ pitting edema is at baseline. EKG shows no new ischemia with a ventricular rate of 110 to 120 beats per minute. Pending labs and chest radiography, you decide to perform a diastolic assessment on echo.

What is a viable method to assess the severity of his diastolic dysfunction?

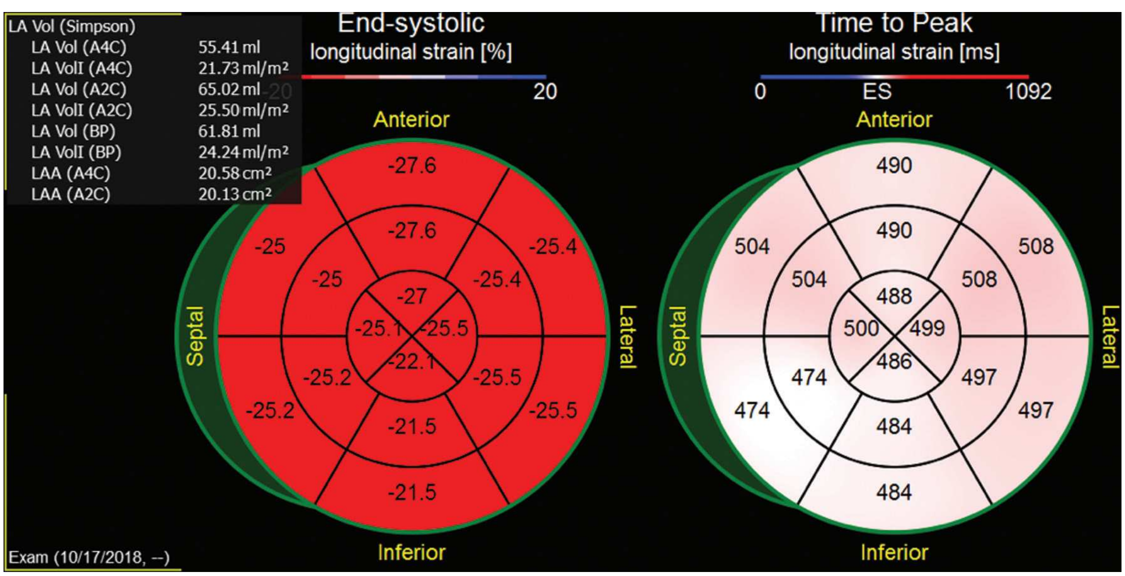

Figure 2.19 *Image courtesy of Drs. Anthony Koppula, MD, and Robin Wachsner, MD, Division of Cardiology, Department of Medicine, Olive View–UCLA Medical Center, Los Angeles, CA.*

A. E/e' measured in three nonconsecutive beats and averaged
B. E/A ratio over one beat
C. LVOT velocity time integral (VTI) over 10 consecutive beats and averaged
D. Presence of LA enlargement

27. A 76-year-old patient presents with respiratory distress and bilateral rales. You perform an echocardiogram that shows a normal qualitative LVEF. You wish to assess diastolic function. Which of the following two modes of Doppler will you use?

A. Spectral PWD and power Doppler
B. Spectral PWD and tissue Doppler
C. Spectral CWD and TDI
D. Spectral CWD and PWD

28. A trainee has performed an A4C view to evaluate a patient with chest pain. He reports concern for a linear thrombus (arrow) in the LV lumen and RV enlargement. What is your response when reviewing his image (Figure 2.20)?

A. Be mindful of screen indicator position and the object is the RV moderator band.
B. Be mindful of screen indicator position and the object is the LV moderator band.
C. Be mindful of screen indicator position and the object is an automatic implantable cardioverter-defibrillator (AICD) wire.
D. The trainee displays appropriate image interpretation.

29. A 56-year-old female with a history of chronic obstructive pulmonary disease (COPD) presents for increasing shortness of breath on exertion over the last 3 months. Her lung examination does not reveal wheeze or rales and her resting SaO_2 is 96%. However, you notice it drop to 85% when she walks to the bathroom. A bedside echocardiogram reveals RA and RV enlargement with normal LV systolic function. Her D-dimer test is negative. What assessments can be helpful?

A. TAPSE
B. (PAT)
C. Pulmonary regurgitant end diastolic gradient
D. All of the above

30. A 35-year-old male without past medical history presents with progressive fatigue and dyspnea on exertion over the past 2 months, now associated with increased nocturnal cough and orthopnea. He has been active all of his life, including racing in marathons every few months. He is now unable to lie supine without respiratory difficulty. His vital signs are within normal limits. Cardiac and pulmonary exam are unremarkable. Chest X-ray reveals mild cardiomegaly with increased vascular markings. EKG is sinus rhythm with normal voltage. You decide to perform a POCUS echocardiogram.

What is *true* about the differential diagnosis of this patient?

A. Hypertrophic cardiomyopathy (HCM) is associated with a thickened myocardial wall (>13 mm) versus typical LVH pattern.

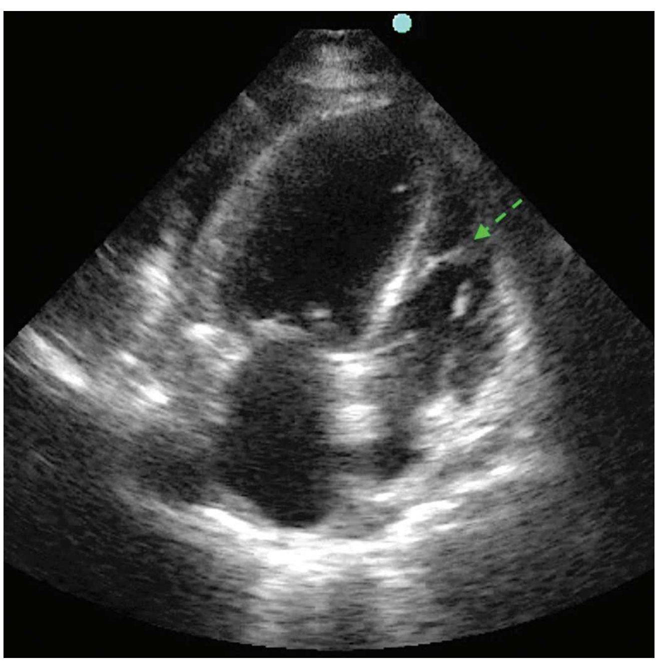

Figure 2.20

Figure 2.21

B. Sarcoidosis is characterized by LV dilation and regional wall thinning and motion abnormalities.
C. Amyloidosis is characterized by diffuse ventricular wall thickening and increased echogenicity of LV walls.
D. All of the above.

31. A 72-year-old male presents with cough, mild chest discomfort, and dyspnea for the past week. Upon triage, an EKG is performed (Figure 2.22).

He is rushed back to a room in the emergency department, where you are able to obtain an A3C window (Figure 2.23, Video 2.18).

What is your most likely diagnosis?

A. Acute anterior MI
B. Pseudoaneurysm
C. LV aneurysm
D. Ventricular thrombus

32. A 56-year-old male presents with 2 days of intermittent chest pain that radiates to his jaw. It is worse with exertion and better with rest. Currently, he is chest pain-free, with a last episode 1 hour prior to presentation. Which of the following abnormalities is associated with the earliest sign of ischemia?

A. ST depressions on EKG
B. Diastolic dysfunction
C. Regional wall motion abnormality
D. Troponin elevation

33. An 85-year-old female with history of aortic stenosis status post bovine valve replacement 10 years ago, congestive heart failure, and stroke presents with syncope. To evaluate for valvular dysfunction on 2D echocardiography, which of the following measurements are used to calculate the dimensionless index?

A. LVOT diameter
B. LVOT velocity
C. Peak aortic jet velocity
D. Both B and C

34. An 18-year-old male presents with palpitations and feeling dizzy for the past 2 hours. He has had a few prior episodes not triggered by exertion or stress, but they usually resolve after a few seconds. He looks anxious but in no acute distress. His BP is 122/72, with an HR of 149, and RR of 19, with O_2 saturation of 99% on room air. His EKG is consistent with supraventricular tachycardia. After he converts successfully with adenosine, you perform an echo (Figure 2.24).

What is your suspected diagnosis?

A. Ebstein's anomaly
B. Atrial septal defect

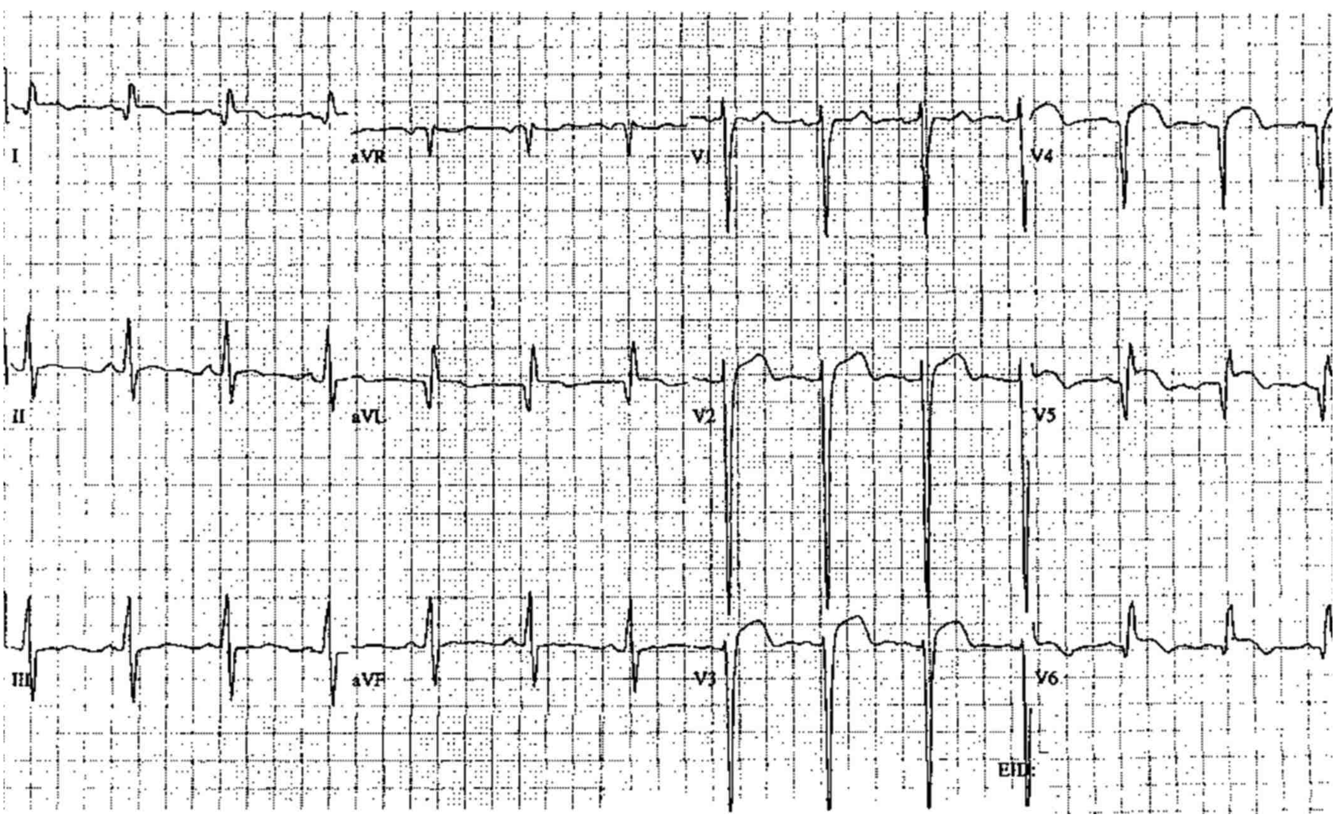

Figure 2.22 From Figure 3 of Engel J, Brady WJ, Mattu A, Perron AD. *Am J Emerg Med*. 2002;20(3):238–242.

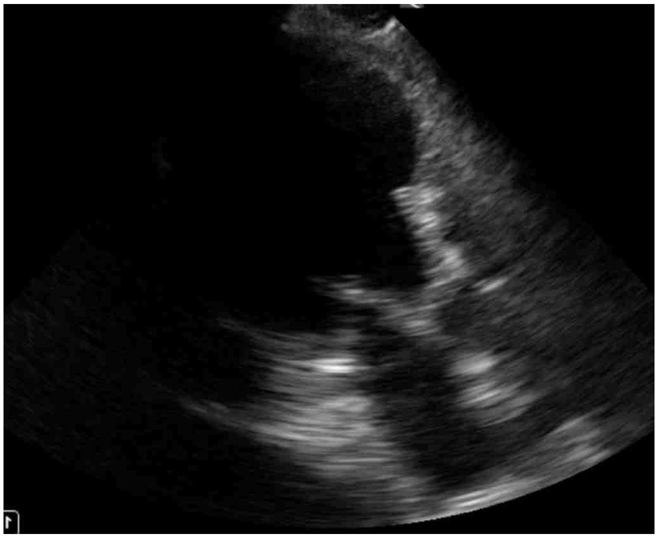

Figure 2.23

C. Transposition of the great arteries (TGA)
D. Both A and B

35. A 36-year-old female presents with chest pain and shortness of breath. She has no known risk factors for cardiac disease in her family or herself. She has noticed decreased exercise tolerance over the last year. Of note, you discover a murmur over her right second intercostal space that she has no prior knowledge of. Figure 2.25a and Figure 2.25b are high parasternal short axis and TEE mid-esophageal long axis windows, respectively.

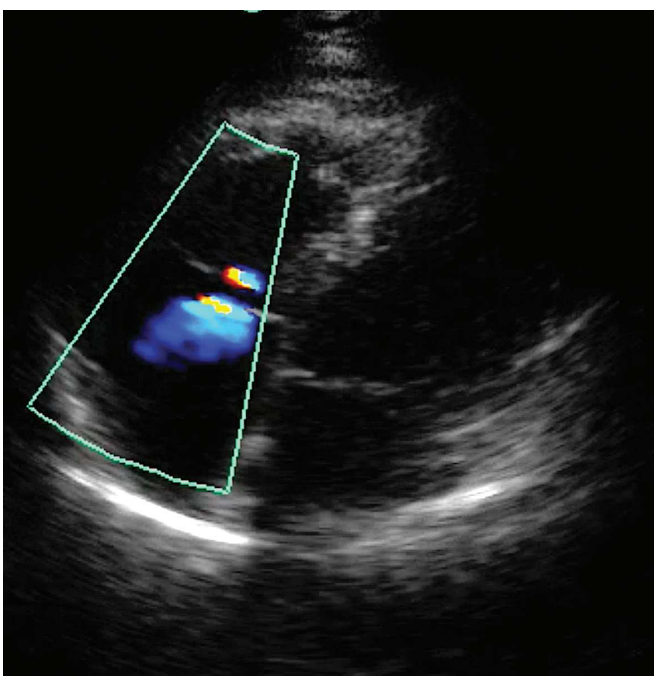

Figure 2.24

What is her diagnosis?

A. Tricuspid regurgitation
B. Bicuspid aortic valve (BAV)
C. Ventricular septal defect
D. Pulmonic stenosis

36. A 52-year-old male presents with acute right hemiparesis and aphasia. A CT angiogram of his head confirms an acute infarct. He has a history of AFib but his EKG today shows a normal sinus rhythm. His international normalized ratio (INR) is 1.3. What are findings associated with cardioembolic stroke?

A. Patent foramen ovale (PFO)
B. Ventricular septal defect (VSD)
C. Spontaneous echo contrast
D. A and C

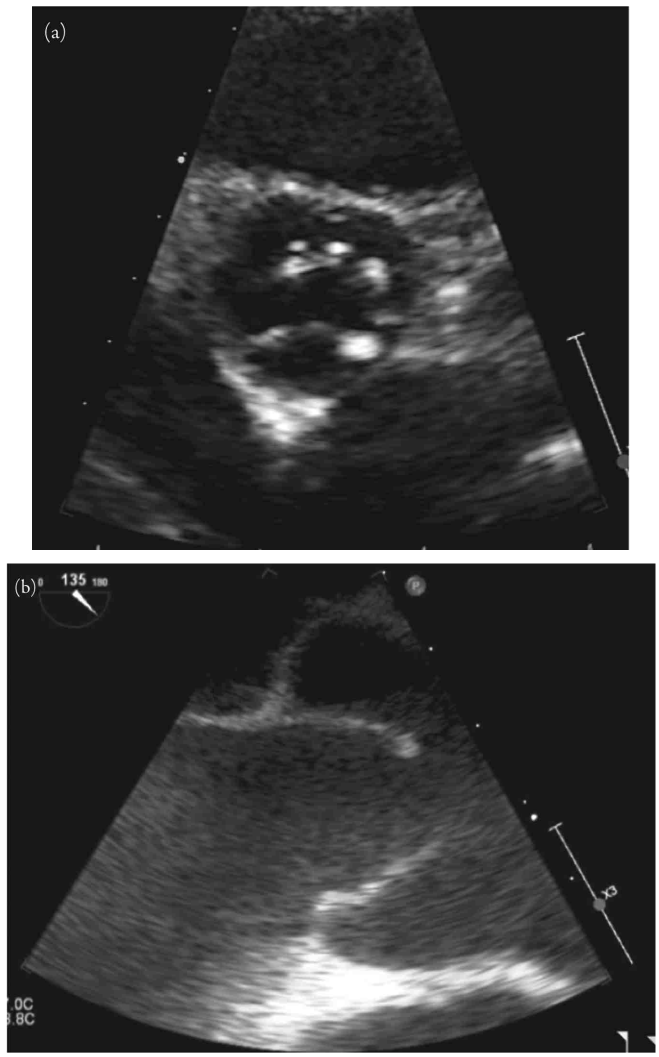

Figure 2.25 *Image courtesy of Drs. Anthony Koppula, MD, and Robin Wachsner, MD, Division of Cardiology, Department of Medicine, Olive View–UCLA Medical Center, Los Angeles, CA.*

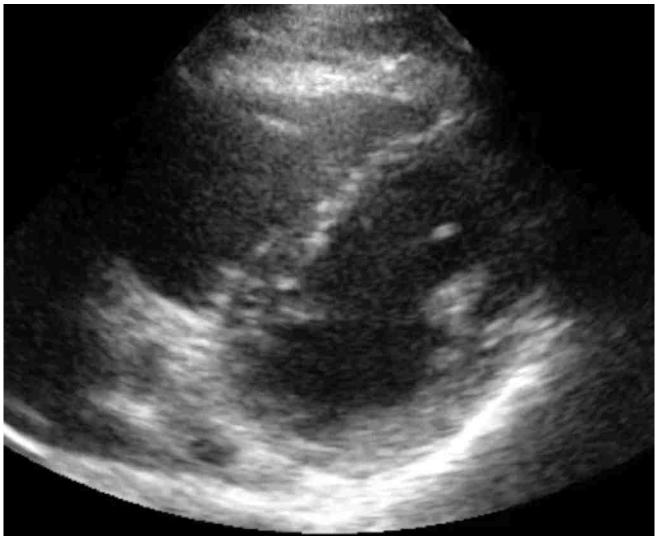

Figure 2.26

37. **A 35-year-old male from Kenya presents with hemoptysis, pleuritic chest pain, and subjective fevers for the past several months. Vital signs are notable for temperature of 100.3°F, BP 100/75, HR 105, RR 20, and SpO_2 98% on nasal cannula. He has JVD and 2+ pitting edema. Chest X-ray reveals a left pulmonary infiltrate and pleural effusion with normal cardiac silhouette. EKG reveals sinus tachycardia. After you place him in isolation and don your respiratory mask, you perform a POCUS echo.**

Which one of the following can be used to differentiate constrictive pericarditis from restrictive cardiomyopathy?

A. TDI
B. Presence of pericardial effusion
C. Ventricular interdependence
D. A and C

38. **A 52-year-old woman presents with pleuritic chest pain and dyspnea for 1 week. Her vital signs are T 37.5°C, BP 126/79, HR 83, RR 18, and SaO_2 100% on room air. She has regular HR and rhythm on her cardiovascular examination, and there is mild expiratory wheezing bilaterally. Her focused echo is shown in Figure 2.26.**

Which echo window is shown? How can the imaging be improved?

A. Subxiphoid—slide probe to the right to avoid air artifact.
B. Parasternal long axis—rotate the probe to identify the true long axis.
C. Apical—slide one intercostal space inferiorly to avoid foreshortening.
D. Parasternal short axis—tilt the probe scan plane apically to avoid a false-positive D-shaped LV.

39. **A 53-year-old man presents with chest pain for the past 2 hours. His vital signs are BP 170/100, HR 93, RR 18, and SpO_2 95% on room air. He has no evidence of fluid overload, and his heart sounds are RRR. You attempt to obtain a parasternal long axis window (Figure 2.27).**

What is the best way to optimize your image?

A. Slide probe to the right to avoid air artifact.
B. Slide 1 intercostal space inferiorly to avoid foreshortening.
C. Rotate the probe to identify the true long axis.
D. Tilt the probe scan plane inferiorly.

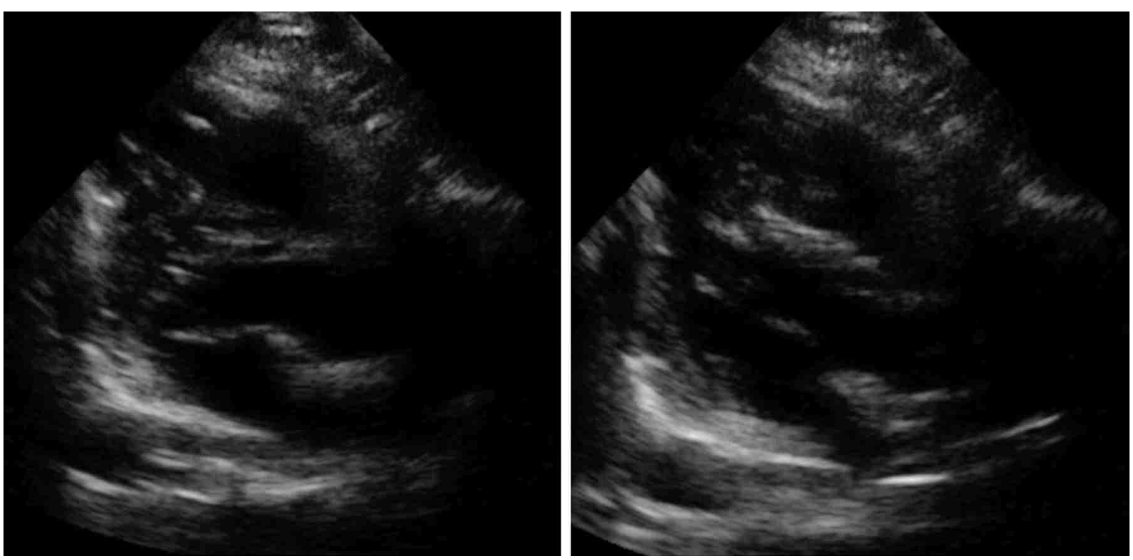

Figure 2.27

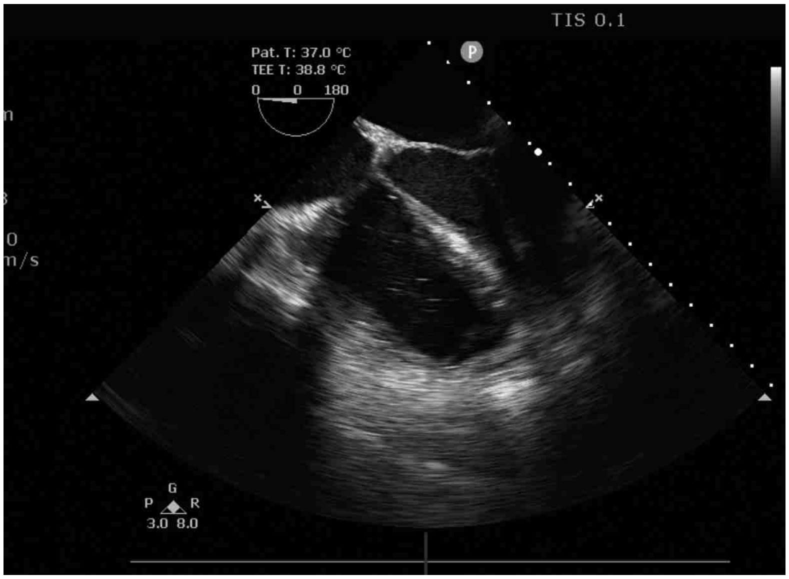

Figure 2.28

40. While on your intensive care unit (ICU) rounds, you are asked about tetralogy of Fallot (TOF) and persistent left superior vena cava. What is true of these congenital diseases?

A. The PAT should be >100 ms in patients with TOF.
B. Large VSDs produce, if any, very faint murmurs.
C. Persistent left superior vena cava should be suspected when there is difficulty with pacemaker placement.
D. All of the above.

41. A 92-year-old male is awaiting in the emergency department for admission to the cardiology unit for a non-STEMI. He suddenly becomes pulseless and his rhythm strip indicates asystole. Chest compressions are initiated and a TEE transducer is placed. What transesophageal view is seen in (Figure 2.28 and Video 2.20)?

A. Mid-esophageal long axis view
B. Deep transgastric long axis view
C. Mid-esophageal four chamber view
D. Transgastric four chamber view

42. An 88-year-old patient with history of coronary artery disease presents in cardiac arrest and has return of spontaneous circulation after 36 minutes of cardiopulmonary resuscitation. The patient is on the ventilator and requiring high doses of an epinephrine drip. You want to assess the patient's hemodynamic status and rule out causes of shock. What is the initial best option?

A. Point-of-care TTE
B. Point-of-care TEE
C. Stat serum lactate level
D. End-tidal CO_2 monitoring

43. A 45-year-old male with no significant past medical history presents with 3 weeks of bilateral lower extremity swelling, fatigue, and weight loss. On exam, patient has 2+ pitting edema to his bilateral lower extremities, lungs sounds are clear, and he has no murmur on cardiac auscultation. His chest X-ray shows cardiomegaly with no pulmonary edema, and his labs are significant for a pro-brain natriuretic peptide (pro-BNP) of 1,100 ng/L with a normal troponin. A bedside ultrasound is performed (Figure 2.29, Video 2.21). What is the most likely cause of this patient's symptoms?

A. Left heart failure
B. Obstruction from myxoma
C. Obstruction from sarcoma
D. Obstruction from thrombus

Figure 2.29 *Courtesy of Dr. Haik Yanashyan, MD.*

ANSWERS

1. EXPLANATION

B. Artificial valve. EPSS is a method of assessing ejection fraction in the parasternal long axis view by applying M-mode orthogonal to the left ventricular (LV) long axis at the mitral valve leaflet tip (Figure 2.30). This is the distance between the interventricular septum (IVS) and anterior mitral valve leaflet at the initiation of diastole, when the valve opens and the LV is maximally contracted. This point corresponds to the initial "E" wave on the M-mode tracing.

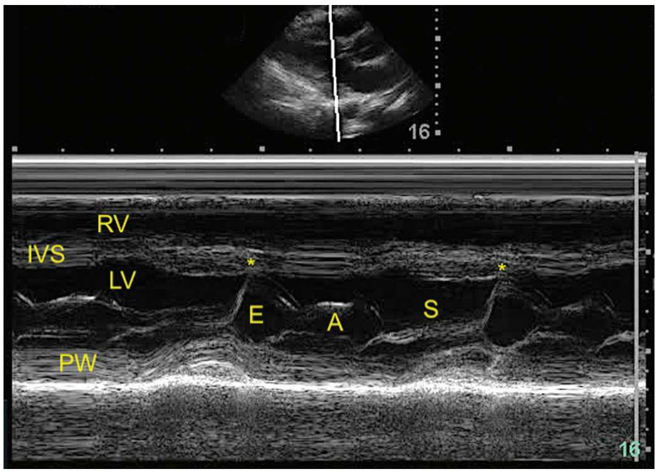

Figure 2.30 **E-point septal separation (EPSS) on M-mode.** The tracing shows the chest wall as the horizontal lines on top, followed by the right ventricle (RV), the interventricular septum (IVS), left ventricle (LV), and posterior LV wall (PW). Inside the LV, the mitral valve is seen opening in the early relaxation (E) and atrial contraction (A) phases of diastole, and closed during systole (S). The EPSS is the distance between the anterior mitral valve leaflet and the IVS at the E point (*). A normal EPSS is ≤7 mm, which is shown in this image. Note that on this same image, IVS and PW thickness change, as well as end diastolic and end systolic LV diameter change can be assessed.

An EPSS measurement of 6 to 7 mm or less correlates to normal systolic function greater than 50% to 55%. An increased separation between the LV septum and mitral leaflet in diastole may indicate reduced ejection fraction. However, certain conditions can make this measurement inaccurate, such as mitral valvular disease and prosthesis, septal hypertrophy (e.g., LV hypertrophy [LVH] and hypertrophic obstructive cardiomyopathy), and arrhythmias.

In these cases, other signs of normal systolic function include:

- change in chamber size >50%.
- change in thickness of the interventricular and posterior LV wall >30%.

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Keywords/Tags: EPSS, E-point septal separation, LVEF, ejection fraction, LV systolic function

Learning Point 1: In patients with artificial mitral valves or those with valvular damage, E-point septal separation (EPSS) cannot be used.

2. EXPLANATION

D. Both A and B. Identifying the pericardium and descending aorta is key to differentiating pericardial and pleural effusions. This particular patient exhibits both pericardial and pleural effusions (Figure 2.31). First, obtain a parasternal long axis view and locate the pericardium, which is the thick fibrous structure surrounding

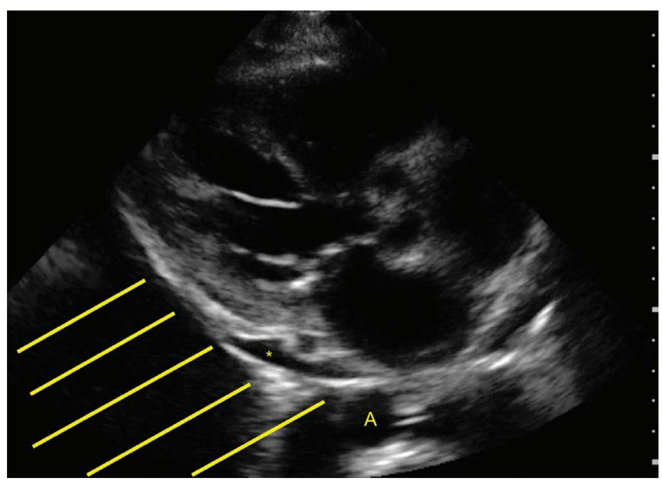

Figure 2.31 **Parasternal long axis window showing a small pericardial and a large pleural effusion.** The pericardial effusion (*) is seen anterior to the descending aorta (A), while the pleural effusion (area indicated by lines) is the large anechoic space adjoining and posterior to the descending aorta.

the heart that will appear hyperechoic. Posterior to the left atrium and pericardium lies the descending aorta. Pericardial effusions lie anterior relative to the descending aorta, while pleural effusions are posteriorly located in the supine or lateral decubitus patient. Multiple views should also be obtained to properly characterize the pericardial effusion and assess for tamponade physiology when clinically indicated.

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Keywords/Tags: Pleural effusion, pericardial effusion, parasternal long axis, PSLA, descending aorta

Learning Point 2: Parasternal long axis windows are best for assessing systolic function as well as the presence of pericardial and pleural effusions.

3. EXPLANATION

D. Parasternal long axis view, in diastolic phase along the posterior pericardium. M-mode and/or 2D echocardiography can be applied in assessing the pericardium and associated pathology. Simple pericardial effusions can be graded according to the smallest diameter from the posterior pericardium in diastole, with small effusions being <1 cm, moderate effusions 1 to 2 cm, and large effusions >2 cm. Loculated or complex pericardial effusions may not appear along the posterior pericardium, so other echo windows may be needed to identify them. Also of note, pericardial effusions become clinically significant by the rate of fluid accumulation, not necessarily the volume, so even a small but rapidly accumulating pericardial effusion can lead to hemodynamic collapse.

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Keywords/Tags: Pericardial effusion, cardiac tamponade

Learning Point 3: Simple, nonloculated pericardial effusions can be graded according to size.

4. EXPLANATION

D. All of the above. EPSS has been shown to be a reliable and accurate measurement in assessing LV systolic function. This is the separation between the IVS and anterior mitral valve leaflet at the initiation of diastole in the parasternal long axis window, when the mitral valve leaflet just opens. However, as in any line measurement, there are important steps to obtaining an accurate EPSS.

- The M-mode line should be perpendicular to the IVS and intersect the tip of the anterior mitral valve leaflet. This measurement is likely to underestimate LV systolic function because the tip is not sampled (Figure 2.32a).
- The parasternal long axis plane used should be at the center of the LV chamber. The mitral valve annulus is thinner in the anterior–posterior segment than at the commissures. In addition, the anterior mitral leaflet is curvilinear in structure. This results in different EPSS measurements depending on the plane of measurement, with more lateral and medial planes underestimating LV systolic function (Figure 2.32b).

Cut-off values for normal EPSS have varied from less than 5 to 7 mm. Early cardiology literature compared EPSS to coronary angiographic ejection fraction measurements. Massie et al. determined EPSS >5.5cm as specific for detecting reduced LV function, while Ahmadpour et al. found an EPSS >7mm as more sensitive in identifying LV ejection fraction (LVEF) <50%. Silverstein et al. extrapolated a formula for determining LV systolic function using EPSS (in mm), with LVEF = 75.5—(2.5 × EPSS). EPSS is less reliable in the presence of septal wall regional wall motion abnormality or hypertrophy, or if there is moderate to severe aortic insufficiency, as the regurgitant jet will attenuate the anterior motion of the mitral valve leaflet.

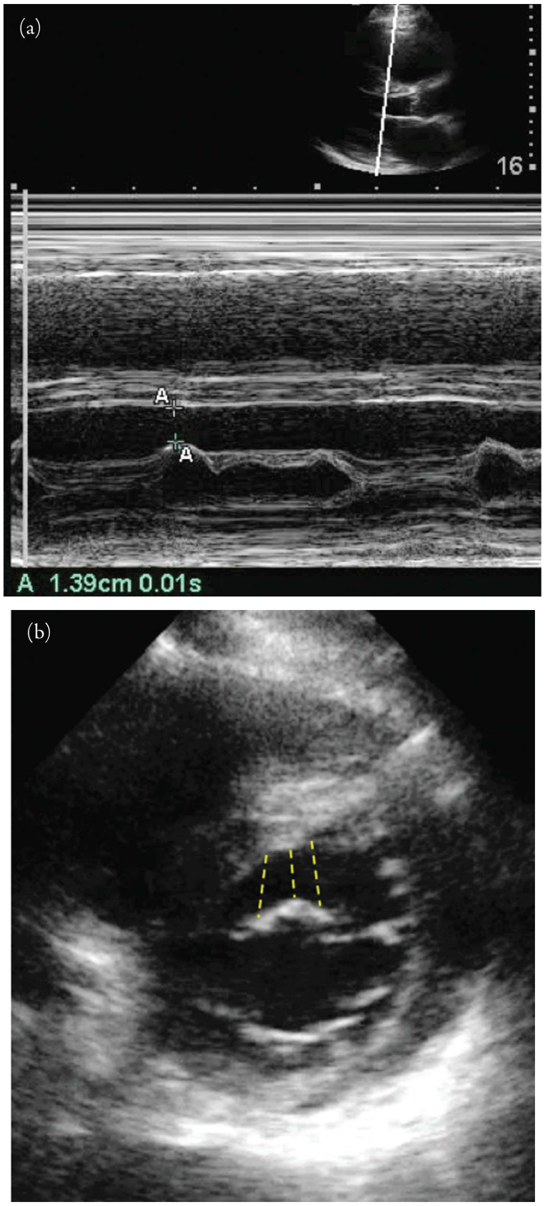

Figure 2.32 (a) **E-point septal separation (EPSS) measured proximal to the mitral leaflet tip.** This measurement leads to an increased EPSS measurement and underestimation of left ventricular systolic function. (b) **E-point septal separation (EPSS) measurements as shown on parasternal short axis window.** Note that the central plane gives a smaller EPSS than the medial or lateral planes. A parasternal long axis plane that is too medial or lateral will underestimate the left ventricular systolic function.

Fractional shortening can also be calculated using the same approach and is described by the LV end diastolic diameter (LVEDD) minus this distance at the end of systole (LVESD), and divided by the LVEDD. There are two ways to calculate the diameter, either from the endocardial borders or in the midwall (between the epicardial and endocardial border). It is expressed as a percentage, with >25% normal for endocardial and >15% for midwall measurements. Unlike EPSS, fractional shortening (FS) can be used when there is mitral valvulopathy, but like EPSS, regional wall motion abnormalities (RWMA), regional hypertrophy, and conduction abnormalities limit its accuracy (Figure 2.33).

Alternatively, emergency physician performed visual estimation of ejection fraction (aka as "eyeballing") has been shown to be accurate compared to cardiologists (Moore et al. 2002).

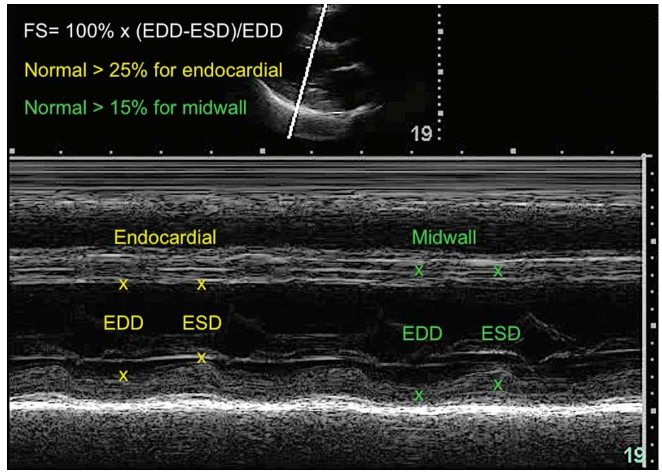

Figure 2.33 **M-mode tracing from a parasternal long axis window showing calculation of fractional shortening.**

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Keywords/Tags: EPSS, E-point septal separation, LVEF, ejection fraction, LV systolic function

Learning Point 4: In assessing LV systolic function on a parasternal long axis view, EPSS, FS, and 'eyeballing' can be used.

5. EXPLANATION

A. Septic shock. A hyperdynamic LV exhibits an ejection fraction >65%, typically coinciding with small chamber size, tachycardia, and increased contractility due to a hypovolemic state as a compensatory mechanism. The LV completely empties in the systolic phase, leading to the "kissing papillary muscle" sign where the papillary muscles appear to touch (or kiss) each other (Figure 2.4). This sign has high specificity for identifying hypovolemia as the potential etiology of shock, with the caveat that it cannot predict volume responsiveness. A cross-sectional area can be measured in the parasternal short axis view at the level of the papillary muscles at end diastole; a value <10 cm^2 is indicative of hypovolemia. Those with chronic LV dysfunction may have falsely normal values and not accurately reflect a hypovolemic or low preload state if present.

Neurogenic shock may show a similar empty LV due to the similar distributive nature as septic shock. However, the presentation does not suggest any trauma to cause neurogenic shock. In addition, on the video, there is evidence of tachycardia, suggesting septic shock is more likely. Cardiogenic shock will show a poorly contractive LV, while obstructive shock will feature either a large pericardial effusion, dilated right ventricle (RV), and/or ventricular interdependence.

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Keywords/Tags: Shock, LVEF, ejection fraction, kissing papillary muscle sign

> **Learning Point 5:** A hyperdynamic LV is seen when the LV chamber empties completely at the end of systole, and tachycardia is present. Often the papillary muscles appear to be touching at this point in the cardiac cycle, known as the "kissing papillary muscle" sign. A hyperdynamic LV is seen in the setting of hypovolemia.

6. EXPLANATION

B. Global assessment for chamber size. This is a patient who most likely has baseline chronic pHTN from long standing obstructive pulmonary disease. Both acute and chronic RV strain can exhibit RV:LV greater than 1:1 (normal ratio is 0.6:1, which is best appreciated in the apical 4-chamber view [A4C]). More reliable findings to indicate a chronic process include:

- RV hypertrophy (>5 mm), as measured optimally on a subxiphoid window (Figure 2.34a).
- RA enlargement, which can be compared with the left atrium on an A4C window. Similar to RV hypertrophy, RA enlargement occurs over time in response to increased RA pressures (RAPs) due to tricuspid regurgitation (Figure 2.34b).
- A pressure gradient above 60 mmHg between RV and RA, or tricuspid regurgitant jet V_{max} > 3.5 m/s, on continuous wave Doppler (CWD). In cases of new and acute pHTN, the RV cannot tolerate afterload pressures exceeding 40 to 50 mmHg before developing obstructive shock. With chronic progression, the RV hypertrophies to compensate for the increased pulmonary artery systolic pressures (PASP; Figure 2.35).

In the absence of pulmonic stenosis, PASP approximate RV systolic pressures (RVSP). The equation for RVSP uses the modified Bernoulli equation, where V_{max} is the peak velocity of the tricuspid regurgitant jet and the RAP:

$$RVSP = RAP + 4 \times V_{max}^{\;2}$$

where, RAP is 3 if the inferior vena cava (IVC) is <2.1 cm in diameter and demonstrates >50% respirophasic change; 15 if the IVC is > 2.1 cm in diameter and demonstrates <50% respirophasic change; and 8 if indeterminate.

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Keywords/Tags: RV dysfunction, RV strain, pulmonary hypertension

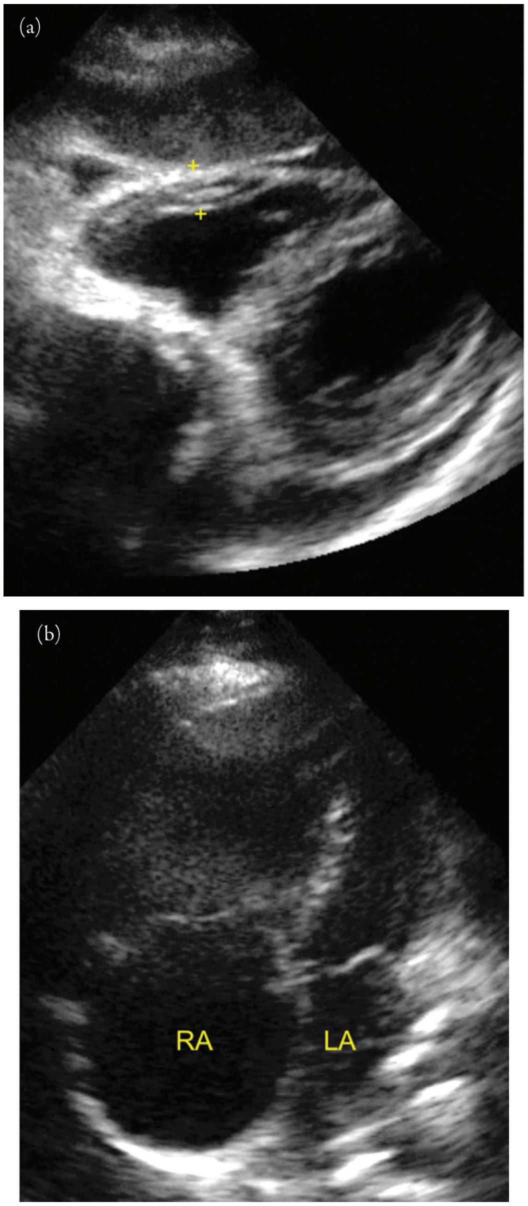

Figure 2.34 (a) **Right ventricular hypertrophy (RVH) on a subcostal window.** This window allows for the most accurate measurement of the RV free wall, as the ultrasound beam is perpendicular to the wall. A wall thickness >5 mm is consistent with RVH. (b) **Right atrial (RA) enlargement on apical 4-chamber window.** While measurements of the major and minor axis, as well as volumetric estimations of the RA can be performed, a quick method is to compare RA size with left atrial size.

Learning Point 6: Signs of chronic pHTN include a thickened RV free wall as well as right atrial (RA) enlargement.

7. EXPLANATION

D. None of the above. On echocardiography, McConnell's sign is defined by RV free wall hypokinesis with relative

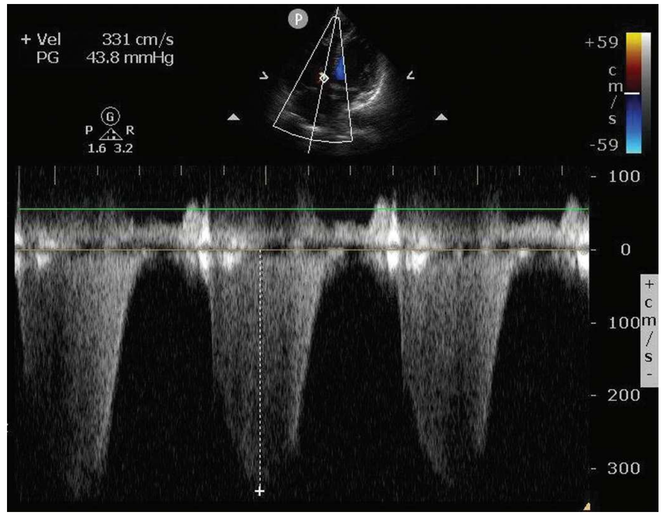

Figure 2.35 **Continuous wave Doppler assessment of the tricuspid regurgitant jet in pulmonary hypertension.** Using the modified Bernoulli equation, the V_{max} of 3.3 m/s leads to a pressure gradient (PG) of 44 mmHg. Assuming the inferior vena cava is >2.1 cm in diameter with <50% respirophasic change, the right atrial pressure is 15 mmHg. Therefore the right ventricular pressure (and pulmonary artery systolic pressure) is 59 mmHg. Pressures exceeding 60 mmHg suggest chronic pulmonary hypertension.

apical sparing, best identified in the A4C view. One proposed mechanism is increasing ischemia to the RV free wall due to pressure overload of the RV, paired with tethering of the RV apex to a hyperdynamic LV apex. In the original research by McConnell et al., specificity was as high as 94% for RV dysfunction in pulmonary embolism. However, subsequent research has shown variability in the specificity of McConnell et al.'s sign for RV dysfunction with pulmonary embolism. Vaid et al. and Mediratta et al. demonstrated the presence of McConnell's sign does not necessarily indicate acute pulmonary embolism, with the former finding only a positive predictive value of 57%. Casazza showed in a series of 201 patients that RV infarction associated with an inferior ST-elevation myocardial infarction (STEMI) was twice as likely to be the cause of McConnell et al.'s sign rather than a pulmonary embolism. Therefore, an initial electrocardiogram (EKG) should be performed to rule out inferior myocardial infarction (MI). Other reported conditions where the sign may be present include chronic pHTN and acute chest syndrome.

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Keywords/Tags: McConnell's sign, RV dysfunction, RV strain, pulmonary embolism, pulmonary hypertension

Learning Point 7: McConnell's sign is seen as a hypokinetic RV with normal or hyperdynamic RV apex. This is seen in acute submassive and massive pulmonary embolism, but can also be seen in patients with RV infarct.

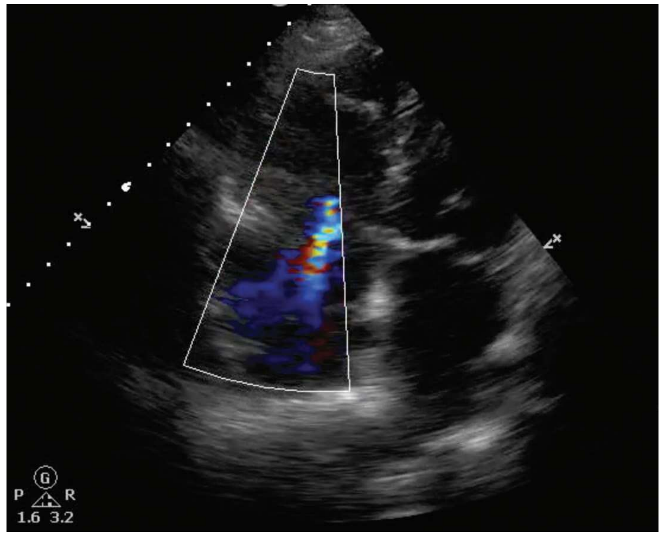

Figure 2.36 **Tricuspid regurgitation in suspected endocarditis.** While many patients may have mild or trace tricuspid regurgitation without symptoms, new moderate or severe tricuspid regurgitation in a patient with risk factors for endocarditis should prompt further workup.

8. EXPLANATION

D. Tricuspid regurgitation. This patient is exhibiting classic signs of endocarditis, most likely tricuspid valve involvement with the history of suspected intravenous drug use. A tricuspid regurgitant murmur can be best heard at the left lower sternal border, with inspiration increasing the intensity of the murmur (Carvalho's sign).

If suspected, echocardiography can confirm the present of a vegetation. The gold standard to identify valvular vegetations is transesophageal echocardiography (TEE) but can be visualized with transthoracic echocardiography (TTE). As the sensitivity of TTE is 50% to 70%, a TEE is recommended in patients with artificial valves, those with suspected paravalvular involvement, or those in which the TTE is nondiagnostic and suspicion is still high for endocarditis. In addition, in the absence of vegetation on TTE, a moderate to severe tricuspid regurgitation in this clinical scenario warrants further work up of endocarditis (Figure 2.36).

The modified Duke criteria for infective endocarditis are as follows:

Major criteria:

1. Positive blood cultures for typical organisms such as *S. viridans, S. bovis, S. aureus, Enterococci,* and HACEK (*Haemophilus, Aggregatibacter, Cardiobacterium, Eikenella, Kingella*);
2. Evidence of endocardial involvement;
3 New valvular regurgitation; and
4. Echocardiographic findings, which may include (i) oscillating intracardiac mass (Figure 2.6, arrows) on the valve or surrounding structures, in the path of the regurgitant jet, or on implanted material without alternative anatomic explanation, (ii) abscess, or (iii) new partial dehiscence of prosthetic valve.

Minor criteria:

1. Predisposing condition or intravenous drug user (IVDU);
2. Fever >38°C;
3. Vascular phenomenon (arterial embolism, septic pulmonary infarctions, mycotic aneurysm, intracranial bleeding, conjunctival hemorrhage, Janeway lesions);
4. Immunologic phenomena (glomerulonephritis, Osler nodes, Roth spots, rheumatoid factor); and
5. Microbiologic or serologic evidence that does not meet major criteria.

The diagnosis for endocarditis is definite if two major criteria, all 5 minor criteria, or 1 major and 3 minor criteria are met. The diagnosis is possible if 3 minor criteria or 1 major and 1 minor criteria are met.

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Keywords/Tags: Endocarditis, Duke's criteria, tricuspid regurgitation, holosystolic murmur

Learning Point 8: Injection drug users with suspected endocarditis typically have tricuspid valve involvement. Vegetations may or may not be visualized on a transthoracic echocardiogram. New moderate to significant tricuspid regurgitation is suggestive of endocarditis in this clinical scenario.

9. EXPLANATION

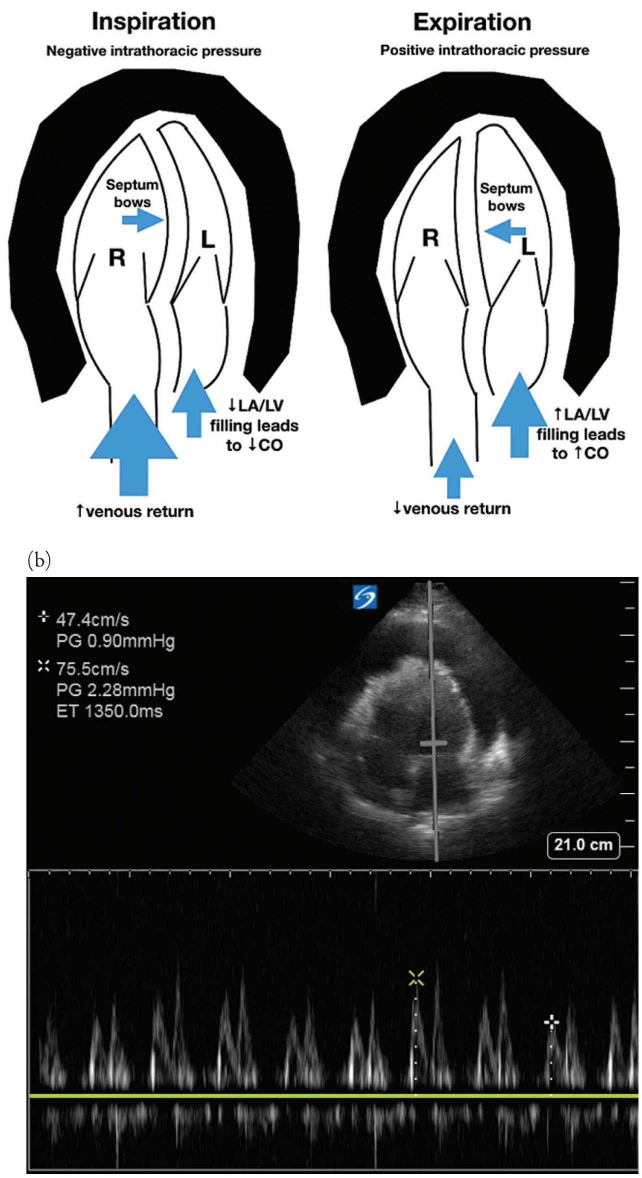
C. Ventricular interdependence. Based on your clinical history and findings, this patient most likely has a cardiac tamponade, which is an equalization of intrapericardial pressure—from a pericardial effusion—with first right and then left heart-filling pressures. Tamponade physiology occurs along a spectrum, as patients may be able to compensate with increased inotropy and chronotropy, as well as vasoconstriction to maintain their systemic pressures. One critical juncture in this spectrum is when one ventricle fills during diastole at the expense of the other. The negative intrathoracic pressures generated during inspiration leads to increased venous return, which leads to increased RV filling. However, since the RV cannot expand into the pericardial effusion, the IVS expands into the LV to accommodate. This leads to decreased LV filling and thus a temporary decrease in the cardiac output. The reverse happens during expiration, when there is decreased venous return, and the LV is allowed to fill at the expense of the RV (Figure 2.37a).

On echocardiography, this can be seen as a bowing of the septum from right to left in diastole, as seen in Figure 2.7 and Video 2.7. On PWD, using an A4C window, this will be seen as exaggerated velocities either on tricuspid or mitral inflow assessment. The criteria is typically an E wave ΔV_{max} > 25% on tricuspid or mitral inflow (Figure 2.37b).

Of note, ventricular interdependence is the basis for pulsus paradoxus, which is seen as a palpable diminution of the radial pulse (or drop in systolic BP ≥10 mmHg) with inspiration.

Carvallo's sign is a physical examination finding associated with tricuspid regurgitation, where deep inspiration enhances the holosystolic murmur present due to the decreased intrathoracic pressure and, hence, increased flow through the regurgitant tricuspid valve. McConnell's sign is an echocardiographic finding where there is hypokinesis of the RV free wall with apical sparing, classically associated with pulmonary embolism with RV dysfunction. Dyskinesia may appear similarly in ischemic causes of regional wall motion abnormality. However, the septal location and presence of other signs of cardiac tamponade render ischemic RWMA less likely.

(a)



(b)

Figure 2.37 (a) **Concept of ventricular interdependence.** Increasing intrapericardial pressures inhibit expansion of both ventricles in diastole. Therefore, expansion of one ventricle occurs at the expense of the other via septal wall movement or bowing. Intrathoracic pressure changes during the respiratory cycle affect cardiac filling and, therefore, lead to transient changes in cardiac output. (b) **Exaggerated diastolic filling velocities in ventricular interdependence.** This mitral inflow spectral tracing shows the undulating pattern seen in ventricular interdependence. Note that ΔV_{max} >25% to 30% is characteristic.

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Keywords/Tags: Pericardial effusion, cardiac tamponade, pulsus paradoxus, ventricular interdependence

Learning Point 9: Ventricular interdependence occurs when RV filling occurs at the expense of LV filling, leading to hypotension. It can occur with both cardiac tamponade and acute RV overload. It is diagnosed via exaggerated tricuspid or mitral inflow variability using pulsed-wave Doppler (PWD).

10. EXPLANATION

A. Right shoulder. On this parasternal long axis view, the probe indicator is on the left side, with the LV apex on the right side. Therefore, the probe indicator must be directed opposite the LV apex, or to the patient's anatomic right shoulder, to produce this image. If the clinician is facing the head of the bed and looking at both the patient and the screen, both the LV apex on the screen and anatomically point to the clinician's right. This convention is intuitive; it is used by many clinicians and is listed as an optional convention by the American College of Emergency Physicians (ACEP).

However, the dominant convention, recommended by major cardiology, critical care, and emergency medicine societies, is to have the LV apex on a parasternal long axis point leftward on the screen. To achieve this, if the screen indicator is on the left, the probe indicator should point toward the apex, or left elbow. If the indicator on the screen is on the right, the probe indicator should point 180 degrees from the apex, or to the right shoulder. Note that in all major conventions, on parasternal short axis, subcostal, and apical windows, the left side of the heart is seen on the right side of the screen (Figure 2.38).

Why are there so many echo conventions? A large part has to do with the history of adoption of echocardiography

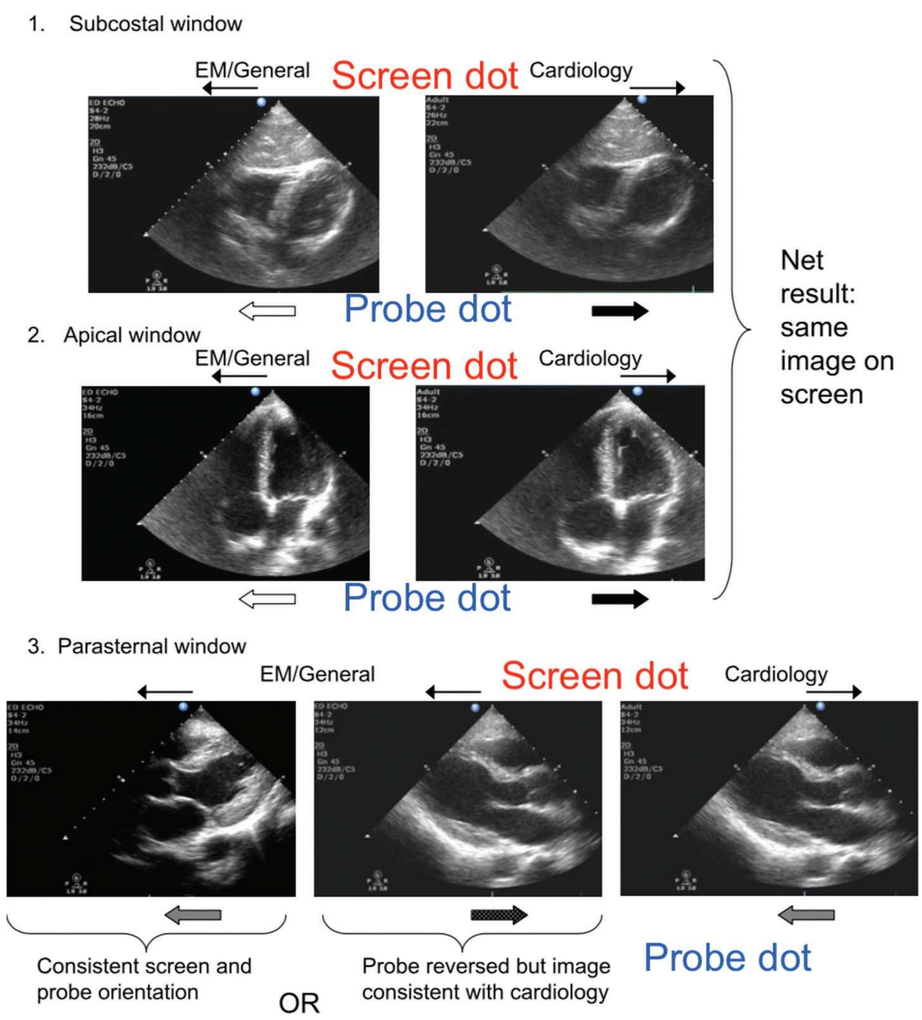

Figure 2.38 **Variations in echocardiographic convention.** Adapted from Figure 3 of Moore C. Current issues with emergency cardiac ultrasound probe and image conventions. *Acad Emerg Med.* 2008; 15(3):278-284.

by different specialties and how each specialty preferred the location of the anatomy on the screen. For example, neonatal echocardiographers prefer seeing the atria at the top of the screen on apical windows, contrary to the apex. The image quality does not differ despite different conventions. What is more important is the ability to identify the anatomical differences that allow for the clinician to quickly locate structures regardless of convention employed. In addition, ultrasound machines allow for customization of screen orientation to suit the preferences of the clinician.

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Keywords/Tags: Orientation, ED echocardiography, cardiology, knobology

Learning Point 10: A general understanding of anatomy and orientation for echocardiography is key, as there are different conventions and approaches that can be a source of controversy.

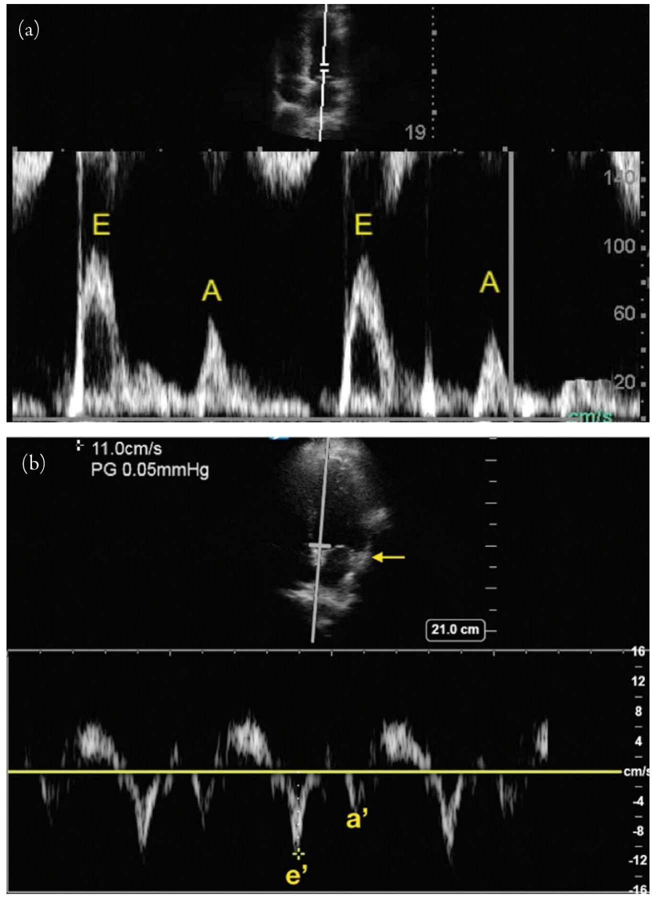

Figure 2.39 (a) **Mitral inflow assessment using pulsed-wave Doppler.** The gate is placed in the left ventricle use distal to the mitral leaflet tips. There are two waves, the early (E) wave associated with left ventricular expansion or active relaxation, and the atrial contraction (A) wave. Note that both waves are optimized using the scale and baseline functions. This tracing shows a normal E/A ratio of 1 to 2. (b) **Tissue Doppler imaging assessment of mitral annular velocities.** This shows a sampling of the left ventricular myocardial velocity at the septal annulus of the mitral valve, with a normal e' (>7 cm/s) measurement of 11 cm/s. The lateral annulus (arrow) can also be assessed, with normal e' >9 cm/s.

11. EXPLANATION

D. B and C. Approximately 50% of congestive heart failure are attributable to diastolic dysfunction with preserved ejection fraction, where the LV exhibits impaired relaxation. While atrial contraction can compensate under certain loading conditions, over time, the LAP rises. When LAP rises above the pulmonary capillary pressures, there is reversal of flow leading to development of pulmonary edema. This can occur with acute significant increases in afterload (e.g., flash pulmonary edema), or over days to weeks as a result of dietary or medication nonadherence. His significantly elevated BP and relative lack of systemic congestion (with minimal peripheral edema) suggests the former etiology.

To elucidate diastolic dysfunction, first spectral PWD is applied with the gated sample supplanted at the tips of the mitral valve leaflets to measure the maximal velocity of the mitral inflow jet in the A4C view (Figure 2.39a). The resultant velocity over time graph through the mitral inflow as displayed reveals two waves. The first wave, or "E" wave, represents the "early" fill phase, which will be the larger of the two waves; the second wave, or "A" wave, is the atrial contraction in the late diastolic phase representing a smaller active fill from the atrial contraction. In normal diastology, the E component is driven by rapid expansion of the LV, leading to a suction effect, which pulls blood from the left atrium to LV. Contrary to its name, this phase is very energy dependent, as muscle expansion only happens when there is ATP to supplant the bound ADP from the actin–myosin chain. Early relaxation accounts for about ⅔ or ¾ of LV filling, with atrial contraction accounting for the rest.

When LV relaxation is impaired, the atria contraction phase compensates, thus leading to a higher A than E wave. As more and more blood pools in the LA, the LAP rises. This accounts for a passive pushing of blood from LA into LV with increasing severity of diastolic dysfunction. In

moderate diastolic dysfunction, the E/A ratio is 1 to 2, similar to normal diastology. To differentiate this "pseudonormal" from normal diastology, tissue Doppler is utilized to assess LV myocardial motion during diastole. This is typically assessed at the lateral and medial annuli of the mitral valve, and gives a similar e' and a' wave, corresponding to the same phase of mitral inflow as E and A (Figure 2.39b). Specifically the e' is directly correlated with the ability of the LV to expand in early relaxation, whereas the a' is a reflection of LV expansion from blood pushed into the LV from atrial contraction. If the e' velocity is less than 7 cm/s at the septal annulus or 9 cm/s at the lateral annulus, this distinguishes pseudonormalization from normal diastology.

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Keywords/Tags: Diastolic dysfunction, diastology, heart failure

> **Learning Point 11:** Isolated diastolic dysfunction presents with preserved ejection fraction, though the LV has reduced capacity to maximally fill, leading to elevated left atrial (LA) pressure (LAP) and cardiogenic pulmonary edema.

12. EXPLANATION

C. Grade 2. Though the E/A ratio appears normal, the septal e' appears to be diminished. This is moderate diastolic dysfunction, in which there is pseudonormalization of the E/A ratio, but the tissue velocities are abnormal. In patients with an unclear presentation, presence of LA enlargement as well as evidence of pulmonary edema pattern (≥3 B lines bilaterally) may be assessed. With worsening congestion, there will be evidence of elevated right heart pressures, so a tricuspid regurgitant jet may be visualized and assessed, as well as a dilated, plethoric IVC.

With worsening afterload and congestion, diastolic function deteriorates to a restrictive pattern, where the LV compliance diminishes and LA pressure continues to rise. Restrictive diastolic dysfunction is characterized by an E/A ratio >2 to 2.5, with e' and a' velocities that are severely diminished, typically <5 cm/s (Figure 2.40).

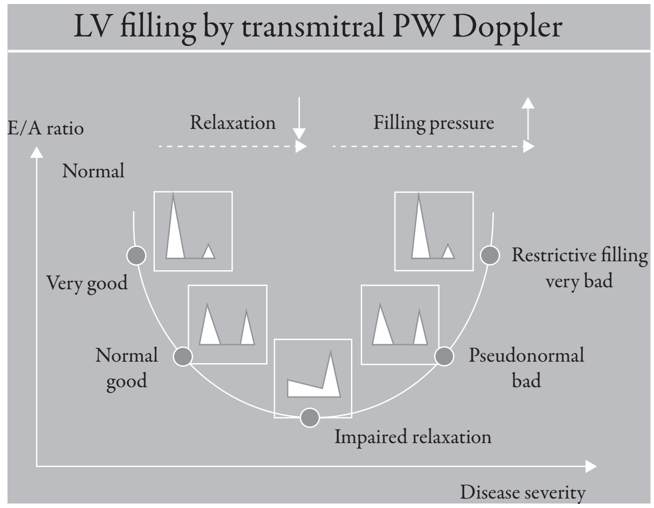

Figure 2.40 **Degrees of diastolic dysfunction in relation to left ventricular relaxation, compliance, and left atrial pressure.** Note that relaxation is represented by e', which diminishes with worsening diastolic dysfunction, while E/A and E/e' increase. From Figure 5.1.7 of Lancellotti P, Cosyns B. Assessment of diastolic function. In: Lancellotti P, Cosyns B, eds. *The EACVI Echo Handbook*. Oxford, UK: Oxford University Press; 2016:167–186.

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Keywords/Tags: Diastolic dysfunction, diastology, heart failure

> **Learning Point 12:** Diastolic dysfunction presents with preserved ejection fraction, though the LV has reduced capacity to maximally fill leading to elevated filling pressures and development of pulmonary and systemic congestion in acute heart failure.

13. EXPLANATION

A. Left anterior descending artery (LAD). Patients that have a non-diagnostic EKG but with features concerning for acute coronary syndrome, may benefit from a POCUS echo to evaluate for regional wall motion abnormality. This patient has a LVH pattern on his EKG, but his POCUS

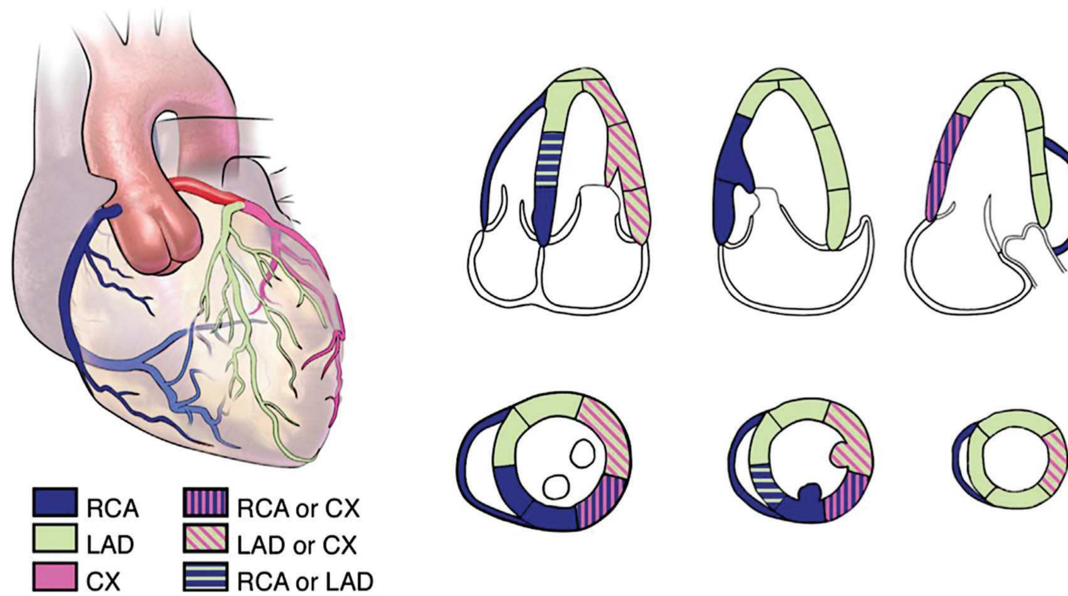

Figure 2.41 **Coronary artery vascular territory.** Adapted from Figure 5 of Lang RM, Badano LP, Mor-Avi V, et al. Recommendations for cardiac chamber quantification by echocardiography in adults: an update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. *J Am Soc Echocardiogr.* 2015;28(1):1–39.e14.

echo demonstrates regional wall motion abnormality involving the anterior wall on the parasternal short axis image, at the level of the papillary muscles. This region corresponds to the left anterior descending (LAD) artery territory (Figure 2.41). Studies have shown relatively high sensitivity of echocardiography-derived RWMA, ranging from 89% to 92%, in identifying transmural infarction (i.e., STEMI). However, RWMA is less sensitive for nontransmural (non-STEMI) ischemia and may be normal.

Note that while there is a more detailed wall motion score index that is performed in a stress echo, this is often not practical or necessary in patients with similar presentations. However, the description of movement is valuable, as it may offer clues as to the extent and acuity of ischemia or infarct:

- Hypokinetic: delay in velocity with <30% systolic thickening, ≤20% of wall thickness ischemic.
- Akinetic: little movement with <10% systolic thickening, >20% wall thickness ischemic.
- Dyskinetic: outward movement during systole, >20% wall thickness ischemic.
- Aneurysmal: outward bulging in systole and diastole, likely old MI.

Also note that in patients with a history of MI, RV dilation, bundle or fascicular branch block, or those that are being paced, it is often difficult to assess ischemic RWMA. RWMA analysis also is poor at identifying ischemic sections of myocardium that appear to be moving normally due to tethering to a nonischemic portion of the LV wall. Lastly, RWMA has only fair inter-rater reliability compared to other echocardiographic methods of assessing ischemia (e.g., strain analysis).

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Keywords/Tags: Myocardial ischemia, myocardial infarction, STEMI, regional wall motion abnormalities, RWMA, focal wall motion abnormalities, FWMA, echocardiography

Learning Point 13: Early echocardiography can detect RWMA due to myocardial ischemia, which is highly sensitive in STEMI but less sensitive in non-STEMI.

14. EXPLANATION

A. Norepinephrine drip. Based on the clinical scenario, a RUSH exam (rapid ultrasound in shock) is performed to identify the etiology for this critically ill patient. There is most likely a combination of sepsis and hypovolemic shock secondary to suspected Clostridium difficile colitis with recent antibiotic use. The images show a collapsible IVC and a flat LV on an off-axis apical 5-chamber (A5C) window. Initial therapy should include aggressive fluid resuscitation and early broad spectrum antibiotics as well as treating the underlying febrile illness with cooling methods and/or antipyretics. Norepinephrine may be considered if, upon reassessment, the patient continues to be hypotensive and there is a plump IVC, distended LV, and/or evidence of bilateral B-lines. These findings would suggest that she has been fluid optimized and, therefore, would require inotropic and/or vasotropic support.

Several protocols have been studied in assessing the critically ill, undifferentiated hypotensive patient. Some evidence has suggested the clinical benefit of POCUS in the setting of hypotension, but unclear improvement in patient mortality. In a retrospective study of symptomatic hypotensive patients by Volpicelli et al., there was good agreement between clinicians' interpretation and ultrasonography altered management in 50% of cases.

In a recent publication by Atkinson et al., which integrated the ACES (Figure 2.42a) and RUSH protocol (Figure 2.42b) in a multicenter randomized control study of undifferentiated hypotensive patients, POCUS did not significantly improve 30-day mortality, estimated 23.5% and 23.8%, respectively, nor secondary outcomes such as length of stay, computed tomography (CT) imaging, inotropic agent use, or fluid resuscitation. A major criticism is that neither ACES or RUSH were meant to be used to assess fluid responsiveness nor to be used in serial assessments. The main purpose of these exams is to identify the

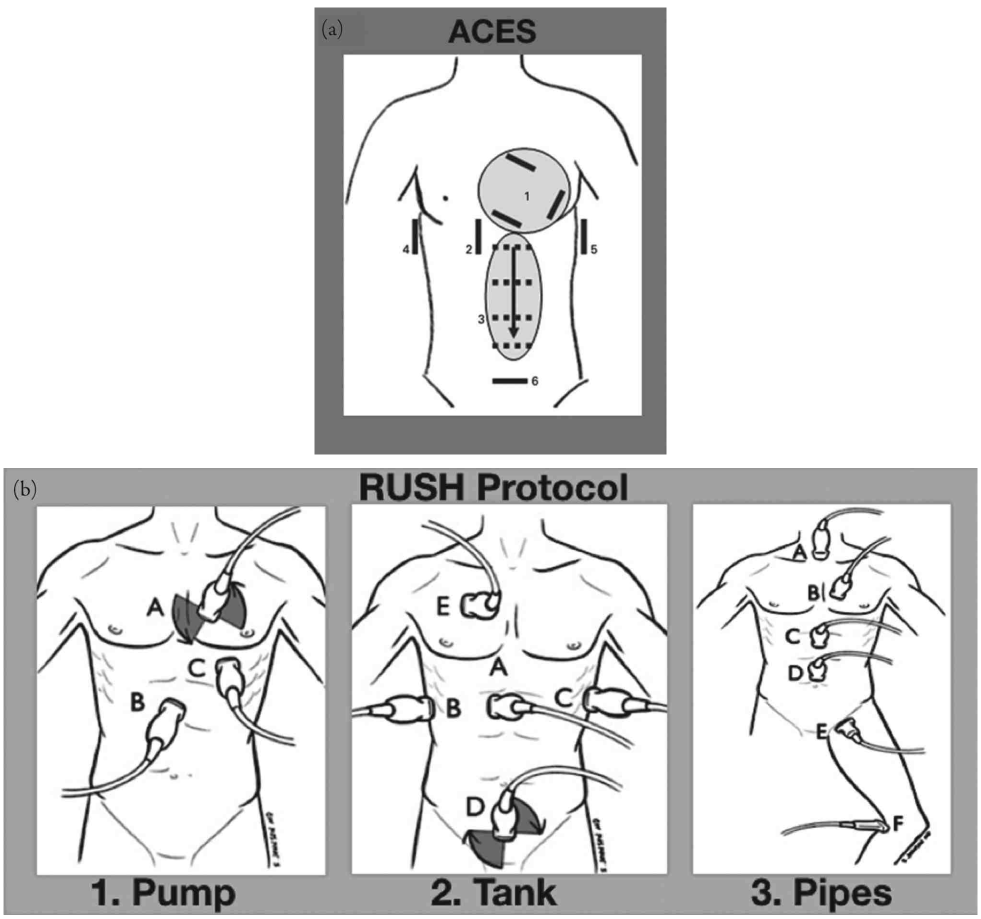

Figure 2.42 (a) **Abdominal and cardiac evaluation with sonography in shock (ACES) protocol.** In ACES, a cardiac assessment is made (1), followed by IVC (2), then abdominal aorta (3), followed by assessment for free fluid in the peritoneum (4, 5, 6). From Figure 1, Atkinson PR et al. Abdominal and cardiac evaluation with sonography in shock (ACES): an approach by emergency physicians for the use of ultrasound in patients with undifferentiated hypotension. *Emerg Med J.* 2009:26:87–91. (b) **The rapid ultrasound in shock (RUSH) protocol.** This 14-step protocol can be broken down into cardiac function ("pump"), fluid status and free fluid ("tank"), and evidence of AAA or DVT ("pipes"). Adapted from Figures 1, 7, and 16. Perera P et al. The RUSH Exam: Rapid ultrasound in shock in the evaluation of the critically ill. *Emerg Med Clin N Am.* 2010;28:29–56.

etiology of shock, and not for assessing hemodynamics noninvasively, nor using this information to manage the majority of septic and hypovolemic shock patients in this study. Other factors include clinician confidence in their abilities to make the diagnosis using POCUS without relying on a confirmatory exam. Lastly, POCUS is not a treatment like antibiotics, but rather a diagnostic modality, so clinical benefit is influenced by many interval factors. Nevertheless, while these protocols can help to rapidly identify the etiology of shock, they have yet to show a mortality benefit for these reasons.

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Keywords/Tags: Shock, sepsis, hypovolemia, RUSH protocol, ACES

Learning Point 14: RUSH, ACES, and FALLS are all ultrasound protocols that can be used to evaluate the etiology of the hypotensive or ill-appearing patient. They share many common windows.

15. EXPLANATION

D. Mitral valve. This is the parasternal short-axis view at the aortic valve. Structures seen on this level of the parasternal short axis are, from the six o'clock position and going clockwise: left atrium, interatrial septum, right atrium, tricuspid valve, RV, pulmonic valve, and main pulmonary artery. In the middle is the aortic valve seen en face, with commissural lines when closed that resemble an upside down "Mercedes Benz" sign.

This window is often one of the most difficult to obtain as it is often shielded by the sternum as well as adjacent lung. However, it has many clinical uses, including (Figure 2.43):

1. Visualization of the LA appendage for spontaneous echo contrast or presence of clots.
2. Visualization of ASD and associated shunts.
3. Assessment of tricuspid regurgitation and RVSP.
4. Assessment of pulmonic stenosis or regurgitation and the ability to obtain more direct PASP in both systole and diastole, as well as measures like pulmonary artery acceleration time (PAT, aka PVAT). These measures are reliable noninvasive measures of pulmonary vascular resistance and compliance.
5. Visualization of the aortic cusps and identification of pathology, such as with calcifications, and congenital bicuspid aortic cusps.
6. Identification of certain types of ventricular septal defects (VSDs; membranous and outlet).

While many of these applications are advanced in scope for the POCUS clinician, it is worthwhile to remember the detailed information that this window can provide.

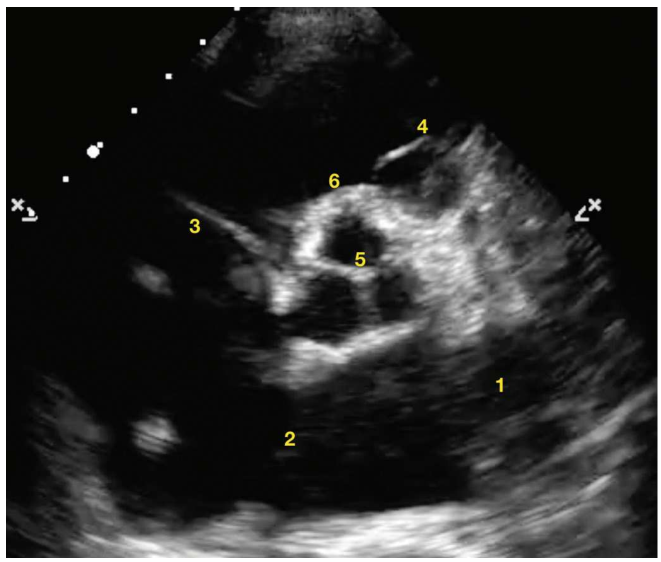

Figure 2.43 **Parasternal short axis window at the level of the aortic valve.** *Figure courtesy of Alan Chiem.*

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Keywords/Tags: Transthoracic echocardiography, echocardiography

Learning Point 15: The parasternal short axis window at the level of the aortic valve shows (from bottom clockwise) the left atrium, interatrial septum, right atrium, tricuspid valve, RV, pulmonic valve, and main pulmonary artery. In the middle is the aortic valve with its 3 cusps.

16. EXPLANATION

A. Right atrial systolic collapse. Figure 2.14 shows an A4C window showing the right atrium inverting or collapsing during systole. This can be discerned because the tricuspid valve is closed, signifying systole. Often, the echo shows a tachycardic heart, making it difficult for the clinician to discern whether this involution occurs during systole or diastole. By freezing the image, the clinician can use the cine loop function to carefully examine the adjacent valve to discern the stage of the cardiac cycle (Figure 2.44; cine loop).

RA collapse occurs in late diastole and early systole as a result of increased intrapericardial pressures on the RA as it fills in systole. This has a sensitivity of >90% but low specificity of about 60–80%. LA systolic collapse is less sensitive but more specific as LA filling pressures are higher than RA filling pressures. IVC plethora can also be a very sensitive indicator of tamponade physiology; however, the specificity is poor (20%–40%) as there are many other causes of increased right-sided pressures.

RV diastolic collapse or inversion is the most specific finding of tamponade (90%–100%) but has lower sensitivity (60%–80%). RV diastolic collapse can be assessed on parasternal or A4C windows, in 2D or M-mode (Figure 2.45).

The finding of exaggerated inflow velocity variation (>25%) associated with ventricular interdependence is more specific than atrial collapse during systole and more sensitive than RV diastolic collapse, but less specific than RV diastolic collapse.

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Keywords/Tags: Pericardial effusion, cardiac tamponade, pericarditis

Learning Point 16: Tamponade occurs along a spectrum, with RA systolic collapse the most sensitive finding on 2D echo. The most specific finding is RV diastolic collapse. Freezing the image and using the cine loop can help with identification of tamponade physiology.

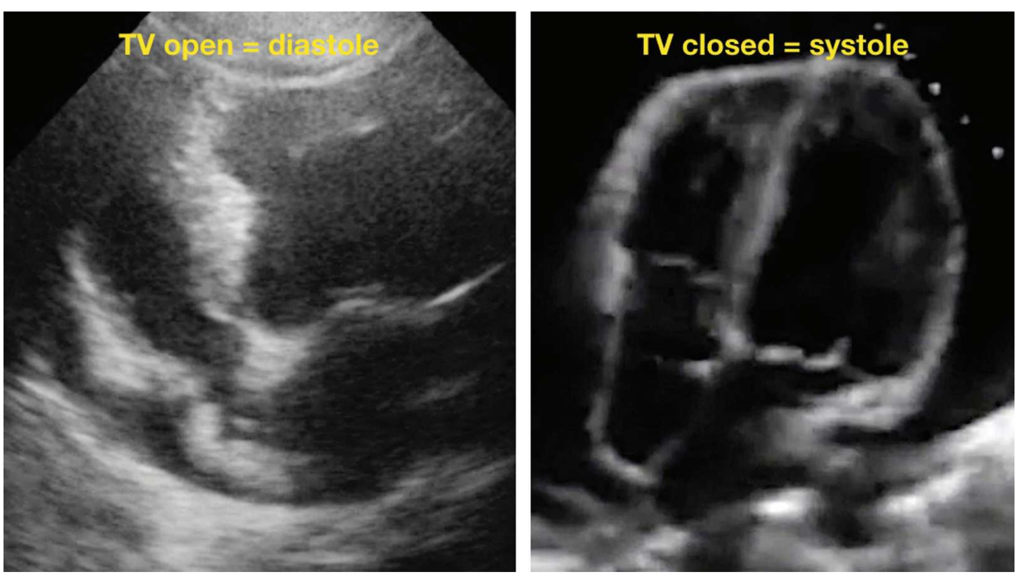

Figure 2.44 **Determining duration of right atrial collapse using the cine loop function.**

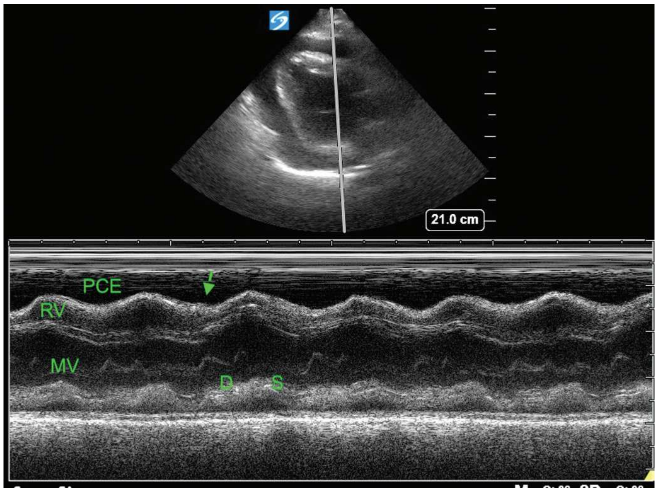

Figure 2.45 **Right ventricular (RV) diastolic collapse on M-mode.** The RV free wall is seen between the RV chamber and the pericardial effusion (PCE). The mitral valve (MV) indicates diastole when there is an "M" pattern, signifying the early and atrial phases of diastole. In systole (S), the mitral valve is closed and appears as a horizontal linear tracing. Note that the RV free wall dips inward (arrow) during late systole as well as early diastole, suggesting tamponade physiology.

17. EXPLANATION

D. Mitral regurgitation. This patient has evidence of a vegetation on her anterior mitral valve leaflet, with likely chordae tendineae involvement leading to an eccentric mitral regurgitation jet directed to the posterior lateral atrial wall. The blue jet going into the LV outflow tract (LVOT) indicates systole, and thus the jet emanating from the valve is confirmed as mitral regurgitation.

Vegetations appear and attach on the upstream side of the affected structure with characteristic irregular contours and exhibit an "oscillating motion" due to its independent movement relative to surrounding structures. While the rate of valvular perforation is higher in aortic endocarditis, up to 50% as compared to 15% in mitral endocarditis, chordae tendineae rupture is more likely to occur with mitral valve complications. Vegetation size has been shown to correlate with risk of complication, with lesions greater than 10 mm associated with 50% of complications and 3-fold increased risk for embolic events. A retrospective analysis of 145 patients with AV or mitral valve infective endocarditis showed a 25% stroke rate, with mitral valve infective endocarditis accounting for 66% of infective endocarditis cases complicated by cerebrovascular accident (CVA).

Emergent cardiothoracic surgery consultation in her case is warranted, as she meets many of the criteria for valvular repair or replacement in infective endocarditis:

- persistent vegetation after systemic embolization;
- anterior mitral leaflet vegetation, especially if >10 mm diameter;
- acute aortic or mitral insufficiency with evidence of either refractory heart failure or hemodynamic instability;
- new heart block;
- or presence of abscess or paravalvular involvement.

In the setting of prosthetic valves, TEE should be first-line as many of the valvular components inhibit adequate visualization by TTE. The threshold for surgical intervention is lower for prosthetic valves, as complications include outflow obstruction, prosthetic valve dehiscence, perivalvular abscess, mycotic aneurysm, fistulas, embolization, acute heart failure, and pericardial effusion/tamponade.

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Keywords/Tags: Valvular heart disease, mitral regurgitation, prosthetic endocarditis, infective endocarditis

Learning Point 17: In patients with suspected endocarditis, an A4C window can be used to assess for vegetations and/or regurgitation of the tricuspid and mitral valves.

18. EXPLANATION

D. Mitral stenosis. The patient has the characteristic "hockey puck" morphology to the mitral leaflets, due to chronic inflammation, thickening, and calcification of the leaflet tips. In general, inflammatory causes of mitral stenosis (e.g., rheumatic heart disease) start at the leaflet tips, while calcific mitral stenosis is a degenerative process that involves mainly the annulus. Patients should undergo consultative echocardiography, where 2D planimetry (Figure 2.46a) and Doppler-based methods (Figure 2.46b) for assessing the mitral valve area (MVA) can be discerned. Whereas a normal MVA is >4.0 cm^2, a MVA <1.0 cm^2 is concerning for severe mitral stenosis.

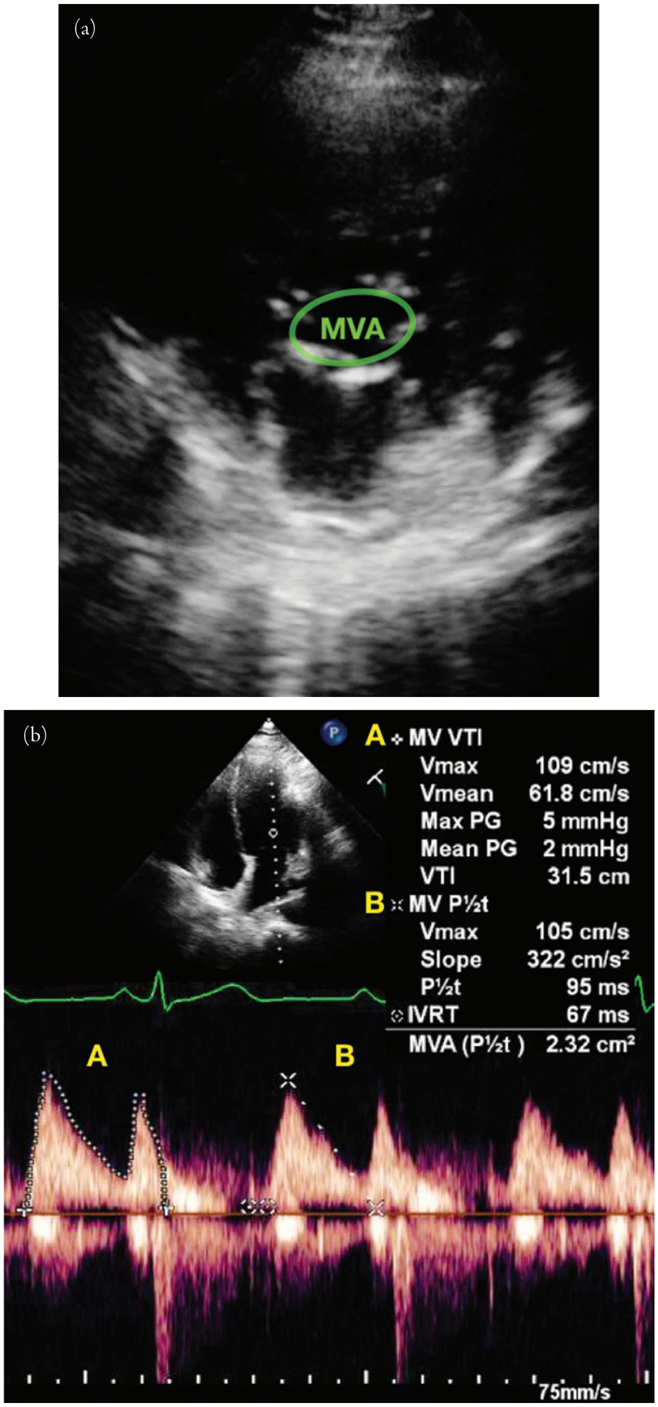

Figure 2.46 (a) **Mitral valve area measurement using planimetry on a parasternal short axis window.** (b) **Doppler-based techniques to estimate the mitral valve area (MVA) in mitral stenosis.** This is a continuous wave Doppler tracing of mitral inflow from an apical 4-chamber window. The first measurement (A) is a tracing of the E and A velocity time integrals (VTI), which generates a mean pressure gradient (MPG) between the LA and LV. An MPG >10 mmHg is considered severe. In (b), the pressure half time (PHT) is traced from the peak of the E wave to the base. A PHT is the time between the maximal mitral gradient to half this gradient. MVA is 220/PHT, so a PHT greater than 220 is indicative of severe mitral stenosis. *Image courtesy of Robin Wachsner, MD, Division of Cardiology, Department of Medicine, Olive View–UCLA Medical Center, Los Angeles, CA.*

Of note, there is expected LA enlargement, as assessed by "the rule of 3s." An imaginary line or M-mode tracing is placed through the aortic valve annulus (Figure 2.47). The rough diameters of the RV, aortic root, and LA should be the same, or about 3 to 4 cm. Any diameter increase relative to the other structures would suggest LA enlargement, RV dilation, and/or aortic root dilation. Common causes of LA enlargement include valvular heart disease, diastolic dysfunction, congestive heart failure, and high cardiac output states such as chronic anemia or hyperthyroidism. One major caveat is that the location of the parasternal window will affect measurements; for example, a low parasternal window will image more of the RV, which will cause it to look larger than the other two chambers.

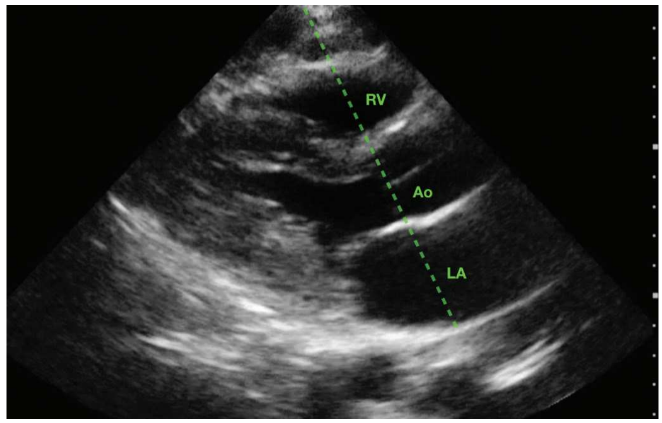

Figure 2.47 **Rapid assessment of chamber enlargement on parasternal long axis using the "Rule of 3s."** Note that each chamber (right ventricle, aorta, left atria) are roughly the same diameter through the dashed line, with about 6 to 7 dashes per chamber.

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Keywords/Tags: Echocardiography, chamber size, ventricular function, left atrial enlargement, mitral stenosis

Learning Point 18: The rule of 3s can be used to globally assess RV or LA enlargement on a parasternal long axis window. A line drawn through the aortic root will show approximately equal diameters of the RV, aortic root, and LA of about 2 to 3 cm. When one chamber appears more enlarged compared to the other chambers, it is usually due to dilatation of the chamber.

19. EXPLANATION

C. Mid-diastolic rumble. This patient has a LA mass as seen on the A4C view. Myxomas are the most common benign primary tumor, found in middle-aged adults, and comprise approximately 50% of benign cardiac tumors. Over 75% of myxomas arise from the left atria, which appear mobile, pedunculated, and heterogenous on echocardiography. Cardiac-related presentations include chest pain, dyspnea, syncope, pulmonary edema, heart failure, MI, arrhythmias, and sudden death, secondary to valvular outflow obstruction. With increase in size and mobility contributing to outflow obstruction, myxomas and other intracardiac masses can mimic mitral stenosis, hence the presence of a diastolic murmur as well as a "tumor plop" on auscultation.

Myxomas can mimic other findings such as thrombus and valvular vegetations, which are key to distinguish. Vegetations arise in the setting of infective endocarditis, move independently from the surrounding structures as they are highly mobile and associated with valvular heart disease. Cardiac thrombus can occur in any of the chambers and valves and, in contrast to vegetations and tumors, are relatively immobile, homogenous, and can be calcified. Thrombi also form in low flow states; therefore, they are associated with poor global or regional systolic dysfunction.

Benign cardiac tumors typically do not undergo malignant transformation; examples include papillary fibroelastoma, rhabdomyoma, fibroma, lipoma, paraganglioma, and hemangioma. Fibroelastomas present similarly in middle-aged to elderly population, most commonly occur on the aortic valves with characteristic shimmering edges; there is an increased risk of systemic embolization (Figure 2.48). Rhabdomyomas and fibromas typically occur in infants and children, with the former associated with tuberous sclerosis. Rhabdomyomas appear more echogenic compared to the myocardium of the ventricular walls. Malignant tumors are even more rare and can be primary or secondary, with sarcomas comprising the most common type of malignant tumor. These can be differentiated using TTE, contrast-enhanced ultrasound, or cardiac magnetic resonance imaging (MRI). Thus, cardiology consultation is warranted when a cardiac mass is visualized on POCUS echocardiography.

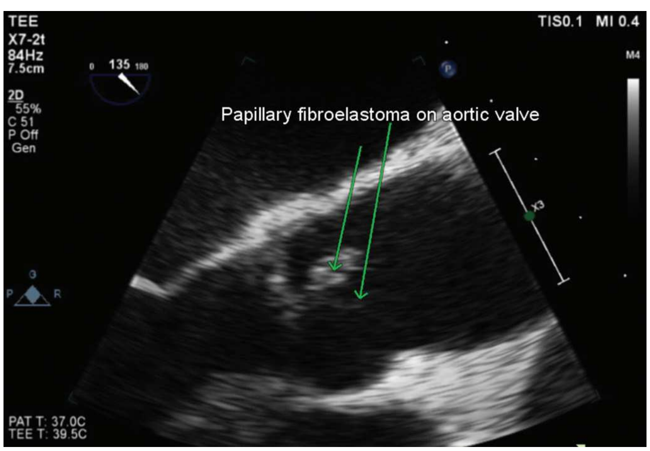

Figure 2.48 **Papillary fibroelastoma on aortic valve visualized on mid-esophageal transesophageal echocardiography window.** *Image courtesy of Anthony Koppula, MD, and Robin Wachsner, MD, Division of Cardiology, Department of Medicine, Olive View–UCLA Medical Center, Los Angeles, CA.*

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Keywords/Tags: Cardiac masses, cardiac tumors, echocardiography, myxoma, diastolic murmur

> **Learning Point 19:** Important cardiac masses to differentiate include valvular vegetations, thrombus, and tumors. Though rare, most tumors are benign; examples may include myxoma, fibroelastoma, and rhabdomyoma. TTE is a good initial imaging modality in assessing and differentiating intracardiac masses.

20. EXPLANATION

D. Use a high molecular weight contrast with diameter of 5μM. Roughly 25% to 33% of formal TTE studies are limited by inability to fully visualize the endocardial border. There may be a higher rate with point-of-care echocardiography, due to operator skill, time constraints, and imaging quality of the machines. This limitation can lead to inaccurate estimations of systolic function as well as Doppler estimations of pressure gradients (Figure 2.49a; echo with contrast).

The 3 determinants of echo contrast use, including dosage, are

- Size: microbubbles need to be smaller than red blood cells (RBCs; <10 uM) to pass through the pulmonary capillaries to opacify the left heart. However, the smaller the size, the less echogenic it becomes.
- Shell: The shell or surface coating contains the gas and protects it from readily diffusing into the circulation.

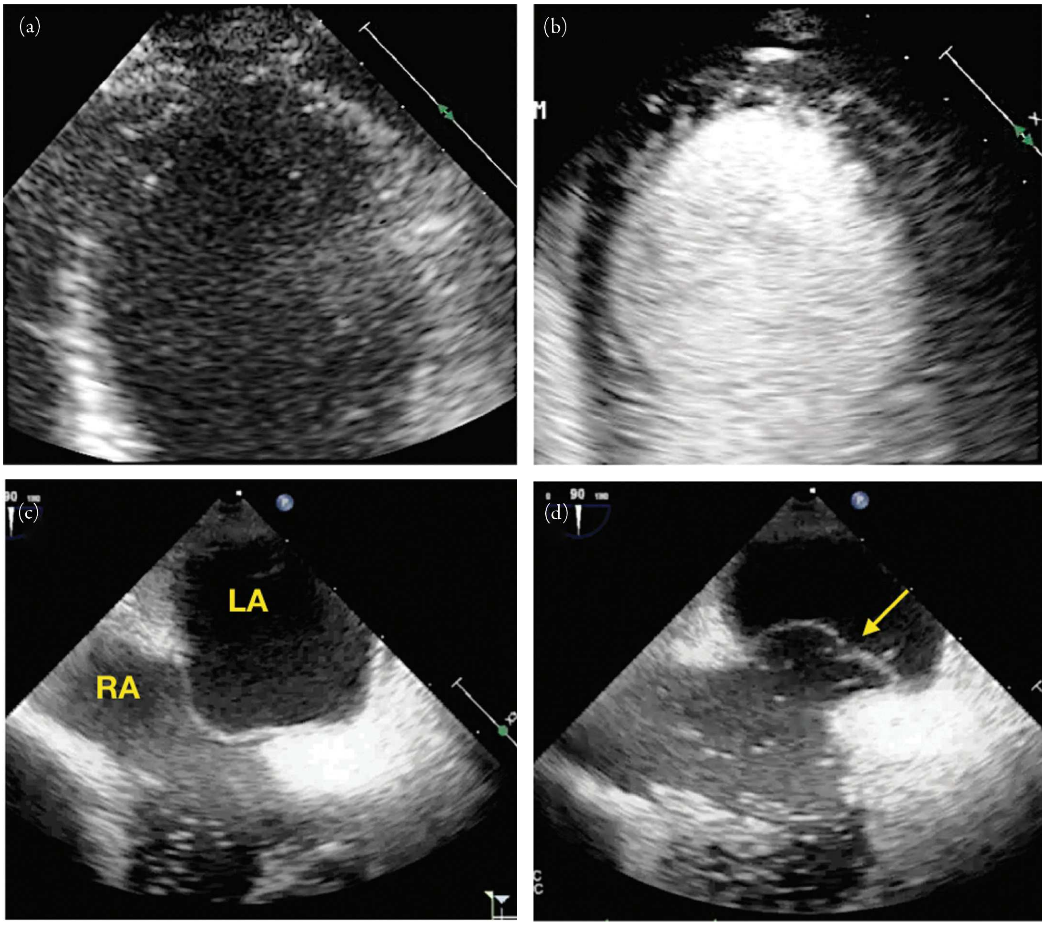

Figure 2.49 **Echo contrast for left ventricular opacification.** This is a side-by-side comparison of a left ventricle (LV) with poorly visualized endocardial border (a), and the same LV imaged using a contrast agent (b). The endocardial border is clearly visualized, and there is no evidence of apical thrombus using the contrast agent. *Images courtesy of Drs. Anthony Koppula, MD, and Robin Wachsner, MD, Division of Cardiology, Department of Medicine, Olive View–UCLA Medical Center, Los Angeles, CA.* **Echo contrast to detect patent foramen ovale.** The image on the (c) shows a bicaval window on transesophageal echocardiography just after agitated saline is injected. When the patient performs a provocative maneuver (e.g., Valsalva, sniff, or cough) to temporarily increase right-sided pressures, there is bowing of the atrial septum with transmission of microbubbles to the left atrium (d), confirming a patent foramen ovale. *Images courtesy of Drs. Anthony Koppula, MD, and Robin Wachsner, MD, Division of Cardiology, Department of Medicine, Olive View–UCLA Medical Center, Los Angeles, CA.*

Coatings that are too rigid may not vibrate when struck by the sound beam, whereas shells that are too pliable may burst more readily and thus decrease the duration of opacification.

- Gas: Air readily diffuses through the shell whereas high molecular weight compounds, like Definity™, are more stable and can last up to 5 minutes after injection. However, there is increased risk of side effects reported with high molecular weight agents versus air-based contrast.

Therefore, a high molecular weight contrast agent with a shell diameter of less than 10 μM will result in the best views of the LV. Saline and agitated saline may be used when confirming central line placement or when assessing for PFOs but diffuse too readily to use as LV opacification (LVO) agents (Figure 2.49b).

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Keywords/Tags: contrast echocardiography, PFO, endocardial border

Learning Point 20: Echo contrast is helpful when the endocardial border cannot be discerned in systolic function assessment, as well as in evaluation of LV thrombi.

21. EXPLANATION

D. Mirror artifact. In mirror artifact, the sound beam hits a highly reflective surface (i.e. pericardium) but is not reflected directly back to the transducer, usually due to the curved or angled nature of that surface. Instead, the beam is reflected into surrounding soft tissue. These echos are detected in a path that differs from the original sound beam. This generates a mirror image artifact that is off-axis and deep to the original image. Often in parasternal long or short axis views, the mitral valve (arrows, Figure 2.18) can be mirrored across the pericardium. The space between the mirrored valve and the pericardium should be equidistant to the space between the real valve and pericardium.

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Keywords/Tags: mirror image artifact

Learning Point 21: Often a mirror image of the heart is seen deep to the pericardium due to the high impedance mismatch between the surrounding air-filled lung and the fluid-filled pericardial sac.

22. EXPLANATION

D. A and C. The patient likely has a tricuspid regurgitant murmur as it is best heard at the lower left sternal border and is holosystolic, increasing in intensity with inspiration. Many POCUS clinicians readily think of the A4C window to best visualize tricuspid regurgitation. However, two alternative windows can visualize and quantify the severity of tricuspid regurgitation. The first is discussed in Figure 2.43, the parasternal short axis window at the level of the aortic valve. This versatile window includes the RV outflow tract and can assess both tricuspid and pulmonic valvulopathies and gradients.

The second window is the RV tricuspid tilt view. This is obtained from a parasternal long axis view with the probe surface slightly tilted or fanned inferiorly, or toward the patient's right hip instead of perpendicular to the patient's chest. This is the RV inflow view, which visualizes the RV, RA, and tricuspid valve. Tricuspid regurgitation analysis with Doppler can be obtained from this view, as well as RVSP measurements that can be used to assess for pHTN (see Figure 2.50).

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Keywords/Tags: RV inflow, RV outflow tract, PASP

Learning Point 22: Tilting the transducer inferiorly from a parasternal long axis view will obtain the RV inflow window, which allows for visualization of the RV, right atrium, and tricuspid valve.

23. EXPLANATION

C. A2C view. The A2C and A3C views allow evaluation of the anterior and inferior LV walls. From a standard A4C view with the probe marker aimed towards the left lateral chest and the screen indicator corresponding to the patient's left side, rotate the probe marker to approximately the 1 o'clock position to obtain the A2C window. You should see the LA, mitral valve, apex, and the anterior and inferior walls of the LV. Further probe marker rotation to the 11 o'clock position will achieve an A3C view, which includes visualization of the aortic valve and aortic root. The A3C is often referred to as the "apical long axis" window as it is in a similar plane as the parasternal long axis, but imaged from the apex. An A5C view can be achieved from an A4C view by tilting the probe more anteriorly. This can also be useful to evaluate the aortic valve and LVOT (Figure 2.51).

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Learning Point 23: From the standard A4C window, rotating the probe will obtain the apical 2-chamber (A2C) and A3C windows. Tilting the probe anteriorly will obtain the A5C window.

24. EXPLANATION

D. EPSS and FS are more accurate than volumetric methods of EF estimation. In general, linear methods of LVEF

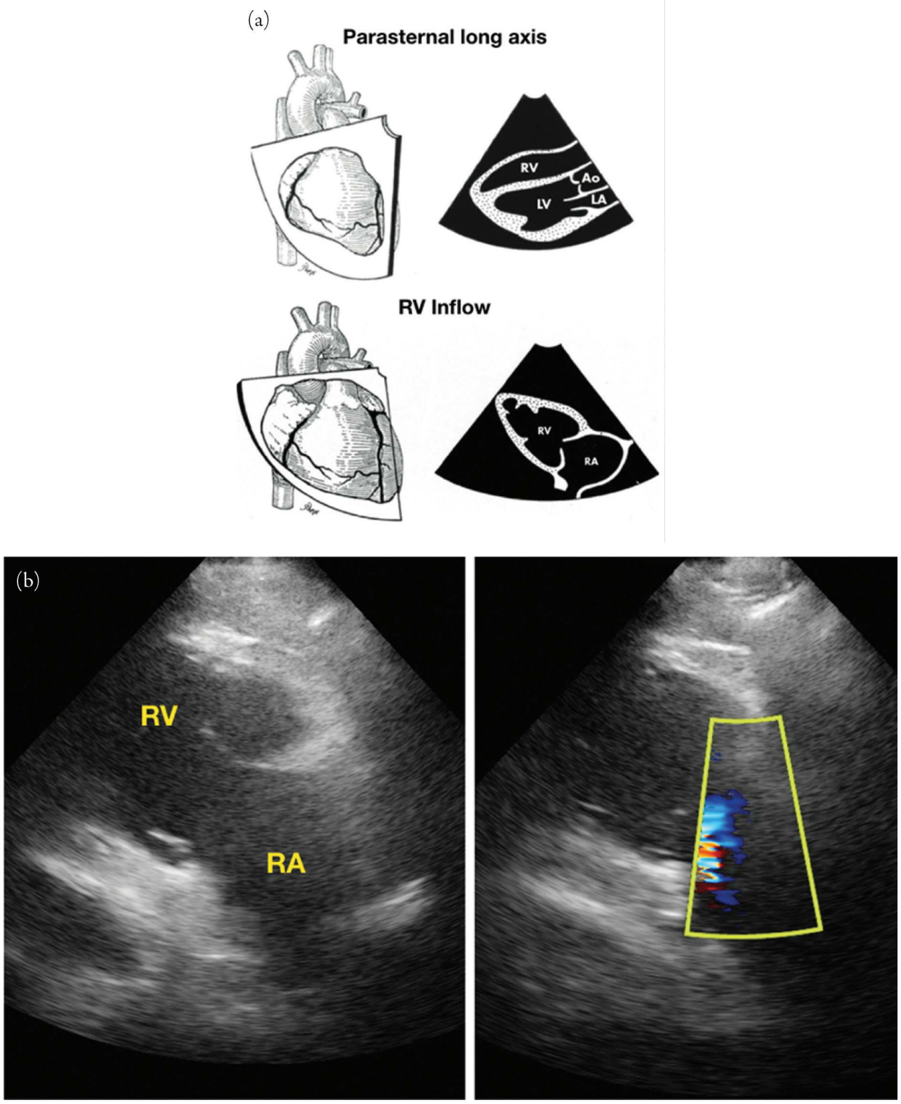

Figure 2.50 (a) **Tilting inferiorly from a parasternal long axis window to obtain the right ventricular inflow (or tricuspid tilt) window.** Adapted from Figures 4 and 5 of Ho SY, Nihoyannopoulos P. Anatomy, echocardiography, and normal right ventricular dimensions. *Heart*. 2006, 92(Suppl I):i2–i13. (b) **Right ventricular inflow views.** The image on the left is a 2D image while the image on the right shows tricuspid regurgitation on color Doppler.

are *less accurate* and more prone to sampling error than 2D and 3D estimations of LVEF. Volumetric estimations of LVEF on 2D echo include Simpson's biplane, area-plane, and Teichholz methods. While most cardiologists visually estimate LVEF, and POCUS clinicians are able to accurately grade LVEF in broad categories (e.g., poor vs. normal), it is important to understand how these 2D methods work. Each method estimates a volume at end systole and end diastole and divides the difference by the end diastolic volume to arrive at LVEF. The assumptions that each method makes on the geometry of the LV may not apply to dilated LVs, which have more globular chambers, or concentrically thickened LV, which may have more cylindrical chambers.

- Simpson's biplane method calculates and sums up the volume of 20 discs to arrive at LV volume. Sonographers must outline the LV area on A4C and A2C, and during both end systole and end diastole. Because the LV chamber is traced in orthogonal planes at 20 regions, it is least prone to geometric assumptions of LV shape, and has the highest correlation with cardiac MRI. It is the recommended 2D quantitative method for LVEF estimation by the American Society of Echocardiography (Figure 2.52).
- Teichholz (cubed) method assumes a partial ellipsoid shape to the LV. It uses a diameter measurement at the mitral annulus and, assuming that the length is twice the diameter, creates a partial ellipsoid (Figure 2.53a).
- Area-length method takes the area at around the mitral valve annulus via tracing, which is then multiplied to the length of the LV from annulus to apex. This assumes almost a bullet shape to the LV (Figure 2.53b).

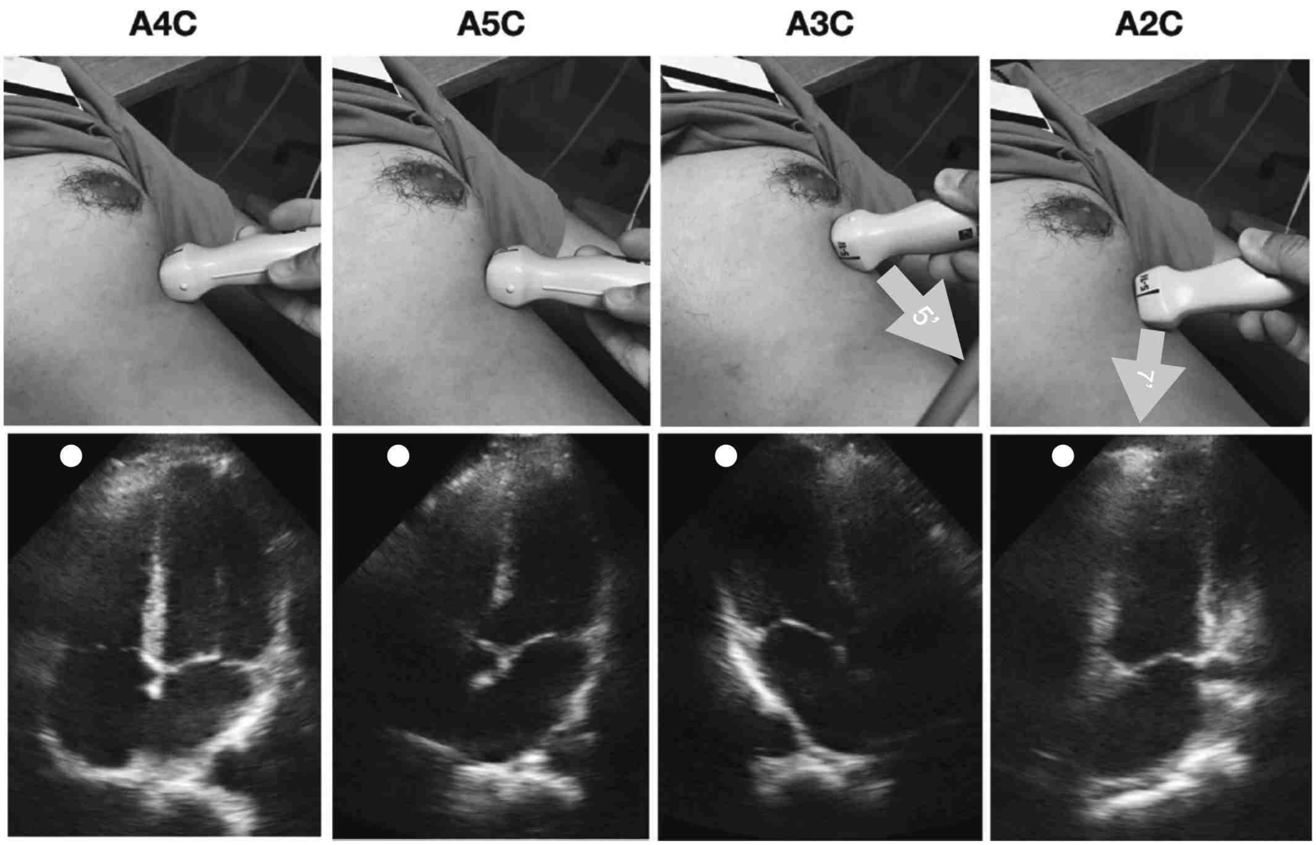

Figure 2.51 **Apical windows.** Starting from an apical 4- chamber (A4C) window, tilting more anteriorly will reveal the A5C window. From A4C rotation counter-clockwise to 5 o'clock will reveal apical 3- chamber window, while rotation to 7 o'clock will reveal the apical 2- chamber window. This is with the screen dot on the left side. Note that if the screen dot is on the right side, the scan planes are the same, but the clock positions are flipped (i.e., 7 o'clock to 1 o'clock and 5 o'clock to 11 o'clock).

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Keywords/Tags: Simpson's biplanar, Teichholz, Area-Length

Learning Point 24: LVEF can be estimated using volume-based changes in the LV during diastole and systole, using the Simpsons and area-length methods. Each method has assumptions of the geometry of the LV chamber, which can lead to inaccuracies in LVEF estimation.

25. EXPLANATION

D. There is no evidence of abnormalities. In Figure 2.19, the left ventricular wall is divided into 16 standard segments, with the base appearing as the outer ring, the mid- apex as the middle ring, and the apex as the inner circle. This is a strain imaging analysis report that shows normal strain (>−20%) of each of the 16 segments of the LV. Strain is defined as the change in length of a myocardial fiber associated with a force or stress such as contraction in systole or expansion in diastole. It is a unitless measurement, defined as 100% × $(L - L_0)/L_0$, where L is the length after the stress/force and L_0 is the original length. Strain imaging can analyze the three different myocardial layers (subendocardial, mid, and subepicardial) as well as the different types of strain (longitudinal, circumferential, and radial; see Figure 2.54). Strain imaging depends on either speckle tracking or TDI. Speckles are unique acoustic patterns specific to a myocardial point; speckle tracking tracks motion of these speckles throughout the cardiac cycle. Speckle tracking is becoming increasingly used as it is angle independent whereas TDI-based strain is dependent on the Doppler angle.

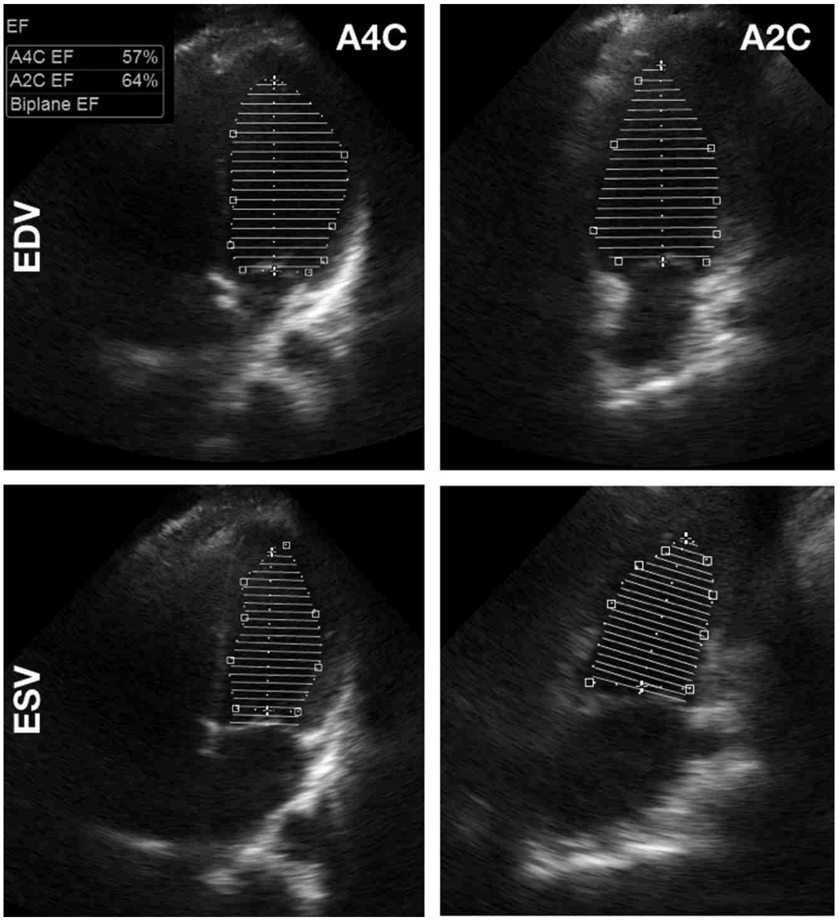

Figure 2.52 **Simpson's biplane method to estimate left ventricular ejection fraction.**

Strain imaging has many applications, including:

- Differentiation of infarcted myocardium from adjacent myocardium that is viable but may be falsely described as infarcted on standard echocardiographic regional wall motion analysis (Figure 2.55).
- Detection of early diastolic heart failure in patients with normal systolic function.
- Diagnosis of the early restrictive (diastolic) physiology that precedes systolic dysfunction in cardiomyopathies like amyloidosis and sarcoidosis.
- In this patient's case, strain imaging can be obtained at baseline and serially for patients that receive chemotherapy—such as anthracyclines and alkylating agents—to detect and initiate treatment for chemotherapy-associated cardiotoxicity.

There are two major limitations with strain imaging. The first is the variability in strain values reported depending on the ultrasound system used. Major echocardiographic societies are working with vendors to standardize values. The second limitation, especially with the POCUS community, is that this technology is not readily available in many POCUS-level machines. However, this is rapidly changing, and every POCUS clinician should be familiar with the concept and utility of strain imaging.

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Learning Point 25: Strain imaging is an emerging echocardiographic technology that allows for accurate

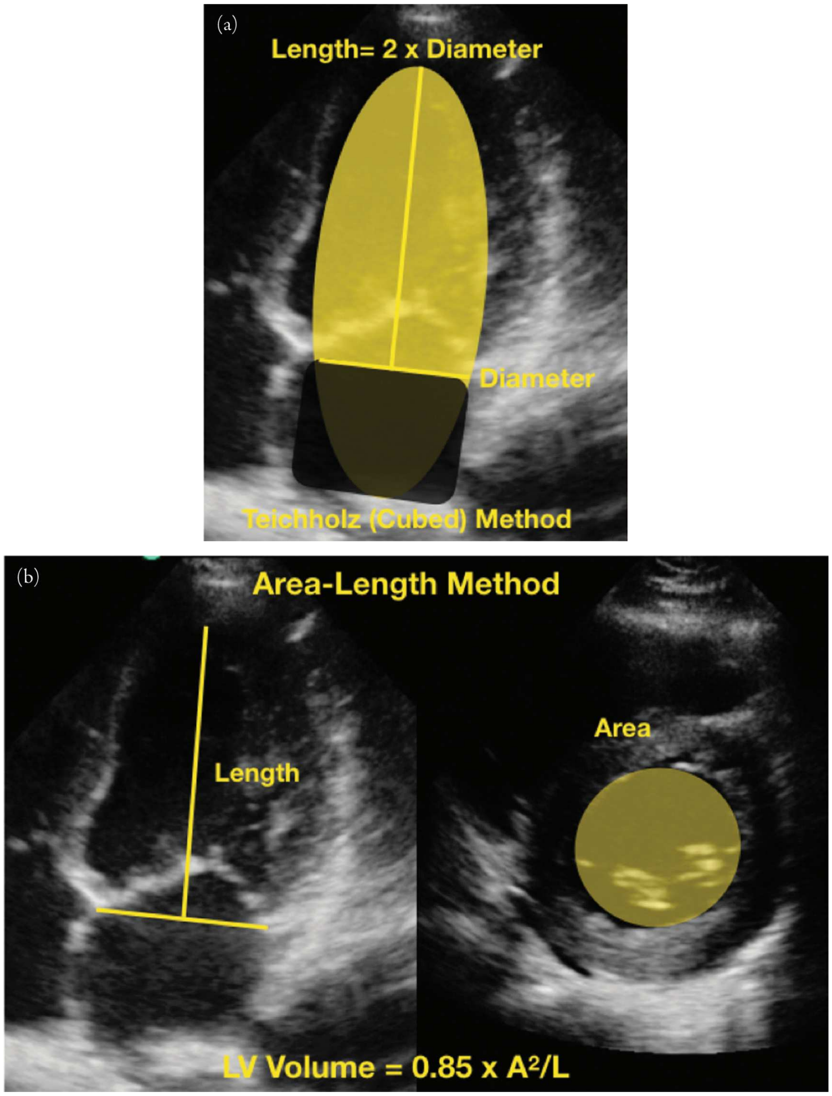

Figure 2.53 (a) **Teichholz method to estimate left ventricular ejection fraction.** (b) **Area-length method to estimate left ventricular ejection fraction.**

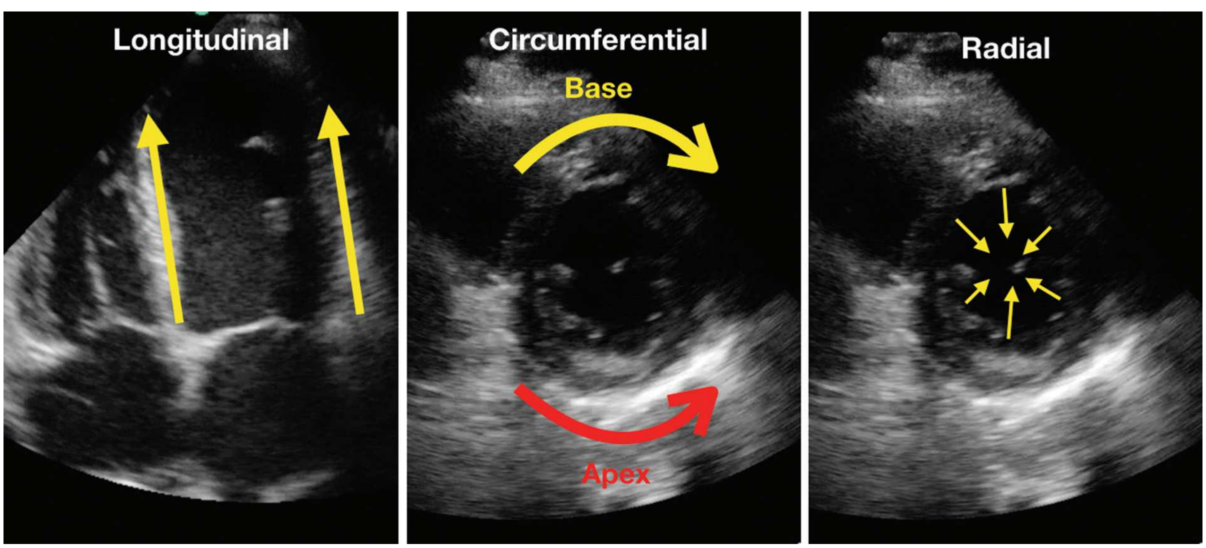

Figure 2.54 **Types of strain.** Each myocardial layer exhibits 3 types of strain pattern: longitudinal contraction from base to apex, circumferential strain, and radial strain. In circumferential strain, the base rotates clockwise while the apex rotates counterclockwise, creating a net twisting effect (often described as wringing a towel). These 3 types of strain occur in unison in systole to eject blood from the left ventricle to the systemic circulation.

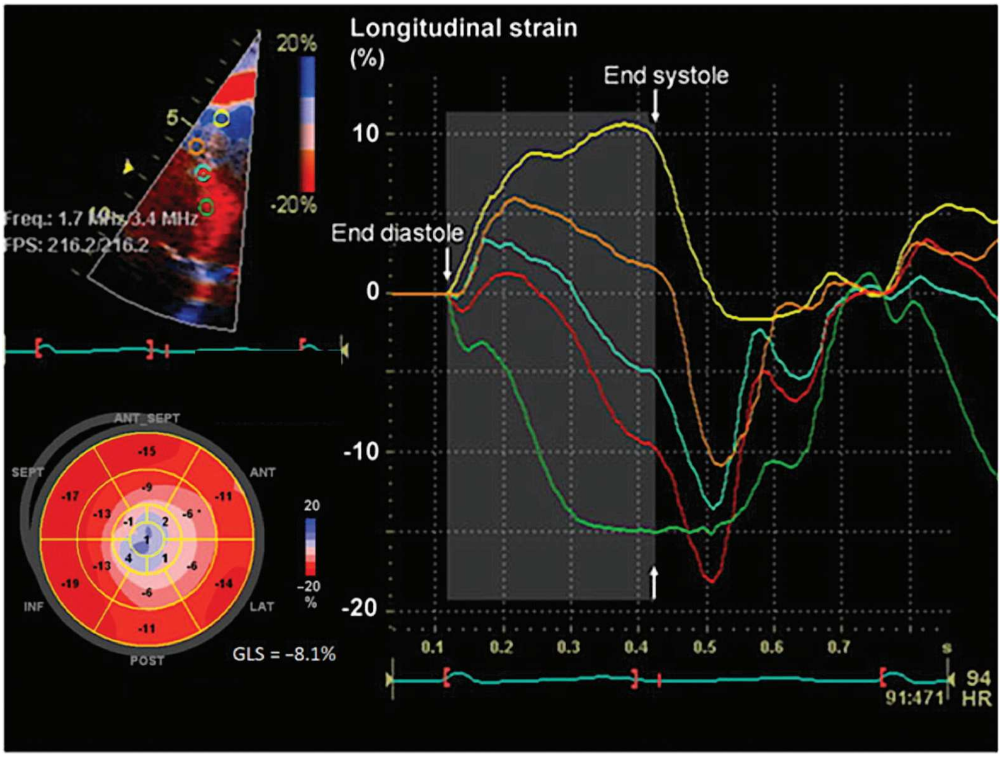

Figure 2.55 **Abnormal strain pattern.** In this patient with an anterior myocardial infarction, there is evidence that the most apical segment (yellow) has infarcted as there is no negative strain that occurs. However, the next 3 segments directed more toward the base (orange, blue, red and green) show lessening degrees of early dyskinesis with late contraction (with negative strain values), implying viable myocardium. This is also reflected numerically in the wall segment chart in the bottom left, with more negative strain values from apex to base. Adapted from Figures 3 and 4 of Smiseth OA, Torp H, Opdahl A, Haugaa KH, Urheim S. Myocardial strain imaging: how useful is it in clinical decision making? *Eur Heart J*. 2006;7(15):1196–1207.

assessment of both systolic and diastolic assessment. Strain refers to the amount of stretch or contraction that occurs within a myocardial fiber from a stress or force. Normal strain is characterized as >20%.

26. EXPLANATION

A. E/e' measured in three nonconsecutive beats and averaged. E/e' can be used if measured over 3 nonconsecutive beats with no more than a 20% difference in HR during this interval as compared to the patient's average HR. Or if the patient is not tachycardic, one E/e' measurement will be accurate. An E/e' >11 corresponds to a LV end-diastolic pressure >15. As the patient has no atrial contraction, there is no appreciable A wave, and thus no ability to assess the E/A ratio in AFib. LVOT VTI to assess LVEF can be calculated in similar fashion for patients with AFib, but is not useful in diastolic assessment. LA enlargement is typically associated with chronically elevated LAP, but is not useful in determining elevated LAP in acute heart failure.

Other feasible methods on POCUS include calculating the deceleration time (DT) of the E wave, as well as the isovolumic relaxation time. A prolonged DT (>200 ms) signifies impaired relaxation without elevated LAP. A shortened DT (<150 ms) is associated with a rapid velocity of blood being pushed into the LV from the LA, as a result of high LAP and low LV compliance. The isovolumic relaxation time (IVRT) is the time between the closure of the aortic valve and the opening of the mitral valve. Similar to the DT, a prolonged IVRT signifies impaired relaxation without elevated filling pressures, whereas an IVRT <65ms signifies restrictive filling. There are many other methods to assess diastolic function in AFib—including sampling of the pulmonary veins and hepatic veins—but IVRT and DT are readily measured on the same spectral tracing of mitral inflow and annular velocities (Figure 2.56).

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Keywords/Tags: E/e', LVOT, velocity time integral, deceleration time, isovolumic relaxation time

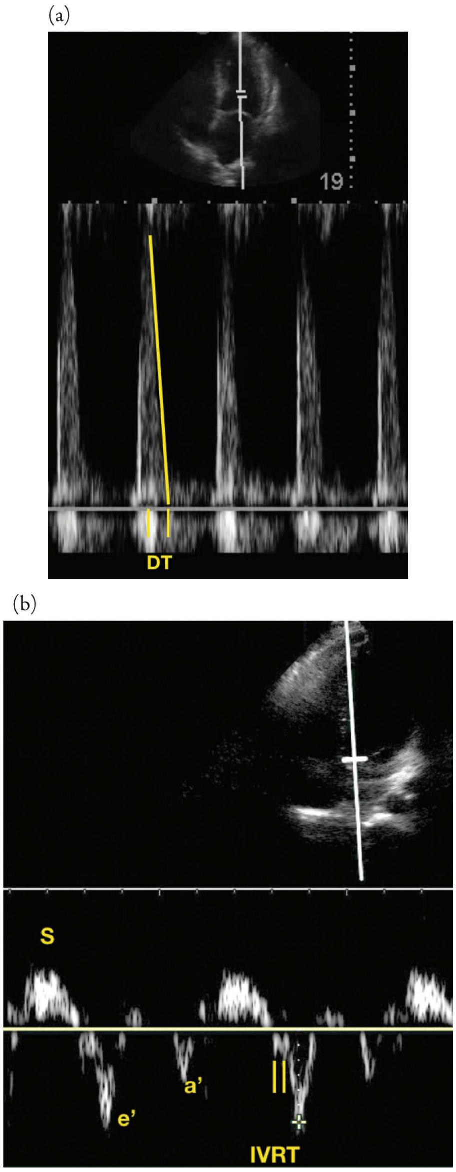

Figure 2.56 (a) **Deceleration time (DT) in atrial fibrillation.** This pulsed-wave Doppler assessment of mitral inflow shows very tall E waves that are narrowly and irregularly spaced, with an absence of A waves. DT is the time from peak of the E wave to return to the base. A DT <150 ms is associated with elevated filling pressures. (b) **Isovolumic relaxation time (IVRT).** This tissue Doppler imaging assessment of the septal annulus of the mitral valve shows normal e' and a' velocities. The isovolumic relaxation time is the interval between closure of the aortic valve and opening of the mitral valve, as represented by the vertical bars. IVRT <65 ms is associated with elevated filling pressures.

Learning Point 26: Atrial fibrillation is associated with diastolic dysfunction and LA enlargement. As the rhythm is irregular, ventricular filling is also irregular. Thus, assessment of diastolic function and LV systolic function should be modified in patients with atrial fibrillation (AFib).

27. EXPLANATION

B. Spectral PWD and TDI. Evaluating diastolic dysfunction requires assessing the velocity of blood flow through the mitral valve during both the relaxation (E) and atrial contraction (A) phase using spectral PWD, and the velocity of tissue that allows filling to occur during these phases (e' and a') using TDI. PWD, TDI, and CWD are considered spectral, or quantitative, Doppler because they allow for tracings of sampled velocities over time.

There is a more detailed discussion on Doppler in the Knobology chapter (Chapter 3), but note that PWD sends pulses to a volume defined by the sampling gates and listens to the return echos. It is able to accurately estimate velocities over a narrow velocity range, defined by the Nyquist limit, but it is prone to aliasing (see Figures 3.7 and 3.29). CWD measures all velocities along a continuously transmitted beam, so it is not prone to aliasing. However, no precise estimation of velocity can be performed at a specific point along the sampling line, also known as "range ambiguity." CWD is very useful for measuring high velocities such as occurs with valvulopathies and pressure gradients.

TDI is essentially PWD but with the range of velocities and the gain turned down, as myocardial tissue moves slower than blood flow (0–20 cm/s vs. 40–200 cm/s) and is much more echogenic than blood. Typically, the waveforms have a negative deflection in diastole and positive deflection in systole, since the LV expands toward the base in diastole and contracts toward the apex in systole.

Color power Doppler (CPD) does not take directionality nor velocity into account, but the presence of moving particles like blood cells. The more moving particles in the sampling box, the more intense the color. CPD is sensitive to low flow areas, so it is used to assess regions where blood flow velocity is not high.

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Quiñones MA, Otto CM, Stoddard M, Waggoner A, Zoghbi WA, Doppler Quantification Task Force of the Nomenclature and Standards Committee of the American Society of Echocardiograp hy: Recommendations for quantification of Doppler echocardiography: a report from the Doppler Quantification Task Force of the Nomenclature and Standards Committee of the American Society of Echocardiography. *J Am Soc Echocardiogr*. 2002;15(2):167–184. doi:10.1067/mje.2002.120202.

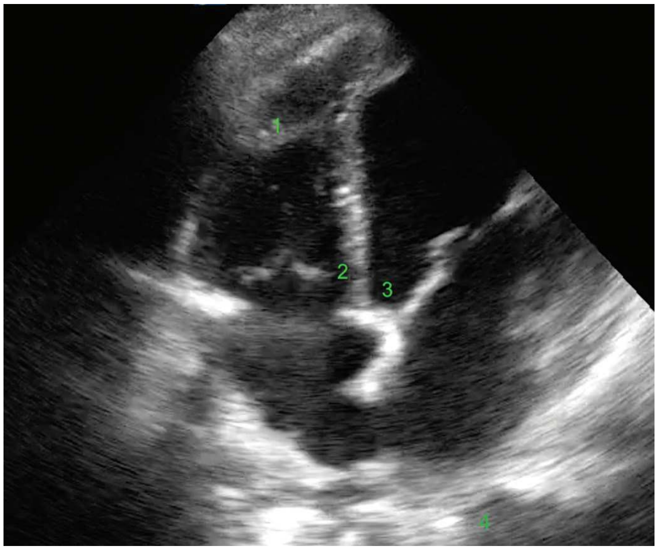

Figure 2.57 **Right ventricle identification.**

Keywords/Tags: pulsed wave Doppler, continous wave Doppler, tissue Doppler imaging, color power Doppler Nyquist limit, aliasing

Learning Point 27: TDI should be used in imaging myocardial velocities, while PWD should be used in estimating inflow and outflow velocities. CWD should be used in estimating the severity of stenotic or regurgitant valves and the pressure gradients that exist between their adjoining chambers.

28. EXPLANATION

A. Be mindful of screen indicator position and the object is the RV moderator band. Especially concerning the apical view, probe and screen indicator relationships are important. The left heart should be displayed on the right side of the screen: if the screen indicator is on the right, the probe indicator should be pointed toward the patient's left, and vice versa. In Figure 2.20, the right heart is on the right, while the left heart is on the left. There are at least 4 indications that this is the case (Figure 2.57):

1. The RV can be identified by its more triangular sail-like shape, thinner walls, and its moderator band. Moderator bands represent trabecular myocardium that extend from the RV anterior papillary muscle to the IVS. The LV may also have a moderator band, but it is rarely seen in adult patients.
2. The tricuspid annulus is more apically displaced relative to the mitral valve annulus.
3. The LVOT will be seen by slightly tilting the probe superiorly and anteriorly. Further tilting in this direction will reveal the aortic valve.
4. Lastly, the descending aorta can be seen in transverse axis next to the left atrium (see Figure 2.57).

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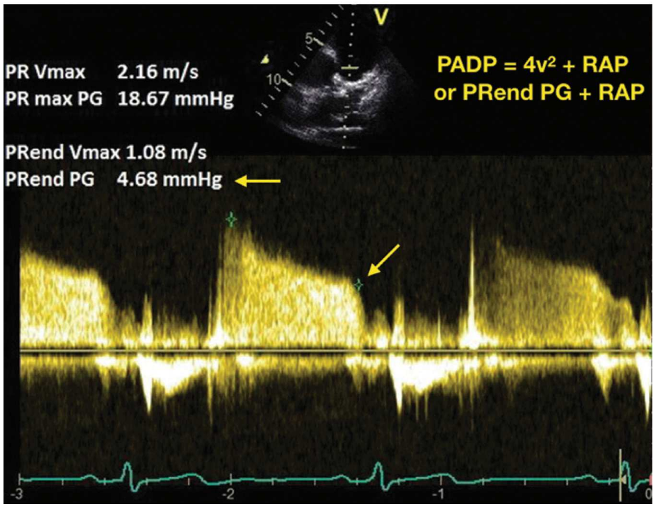
Learning Point 28: The RV can be identified by the thinner walls, moderator band, and the lack of the central aortic valve with tilting the scan plane anteriorly or superiorly.

29. EXPLANATION

D. All of the above. COPD is a major cause of pHTN, specifically in Group 3 of the Evian/WHO classification for pHTN. The diagnosis and work-up of pHTN is complex. However the POCUS clinician, when evaluating undifferentiated patients with dyspnea, can consider some common measurements that may help lead to the diagnosis of pHTN. Briefly, the diagnosis of pHTN is a mean pulmonary artery pressure (mPAP) >25 mmHg. Common echo-based ways to calculate mPAP are

1. ⅓(PASP) + ⅔(pulmonary artery diastolic pressure [PADP]), where PASP can be calculated using the modified Bernouli formula for RVSP.
2. Figure 2.58a shows how PADP can be estimated if there is presence of a pulmonary regurgitation (PR) jet on the parasternal short axis view at the base/aortic valve. It is PADP = $4v^2$ + RAP, where v is the end diastolic PR jet V_{max}. However, a PR jet is relatively uncommon and can be difficult to obtain.
3. Figure 2.58b shows how mPAP can also be estimated using the PAT. PAT is the duration between ejection of blood from RV to PA, and its maximal velocity. A PAT <105 ms is associated with pHTN. mPAP can also be derived from PAT, where mPAP = 79 – (0.45 × PAT).
4. RVSP >50 to 60 mmHg should highly suggest pHTN. In addition, in patients known to have pHTN, RVSP elevation from baseline can be used to diagnosis acute-on-chronic pHTN.

(a)



(b)

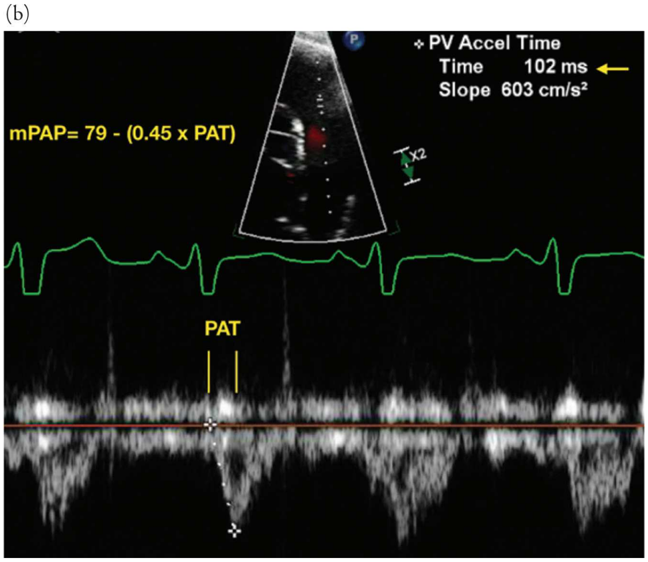


Figure 2.58 (a) **Pulmonary artery diastolic pressure (PADP) estimation.** A pulmonic valve regurgitation jet must be visualized to calculate PADP. There is an early and end-diastolic peak; use the V_{max} of, or pressure gradient associated with, the end-diastolic peak (arrows) to calculate PADP. Right atrial pressure (RAP) is estimated with inferior vena cava respirophasic variability. Adapted from Figure 3 of Parasuraman S, Walker S, Loudon BL, et al. Assessment of pulmonary artery pressure by echocardiography: a comprehensive review. *Int J Cardiol Heart Vasc.* 2016;12:45–51. (b) **Pulmonary artery velocity acceleration time (PAT).** *Image courtesy of Drs. Anthony Koppula, MD, and Robin Wachsner, MD, Division of Cardiology, Department of Medicine, Olive View–UCLA Medical Center, Los Angeles, CA.*

5. There are also systolic measurements of the RV that can be used to help with right heart complications of pHTN. TAPSE is measured using M-mode of the lateral tricuspid annulus on an A4C view. During systole the RV (as measured at the annulus) moves toward the apex, with a normal TAPSE >25 mm. Similarly, S' is the velocity of movement of the annulus on TDI. TAPSE <16mm and S' <10 cm/s are associated with reduced RV systolic function (see Figure 2.59).

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Keywords/Tags: pulmonary hypertension, mean pulmonary artery pressure, pulmonary artery diastolic pressure, pulmonary artery velocity acceleration time, tricuspid annular plane systolic excursion

Learning Point 29: When performing right heart assessment, systolic function can be assessed with both tricuspid annular plane systolic excursion (TAPSE) and S' on TDI. Pulmonary hypertension can be diagnosed by mean PASP >25 mmHg.

30. EXPLANATION

D. All of the above. HCM and infiltrative cardiomyopathies like amyloidosis and sarcoidosis can have similar appearances on echocardiography. For a young patient with no prior medical history and new heart failure symptoms, the index of suspicion should be high for an infiltrative cardiomyopathy or HCM. Clues to help with the diagnosis are:

- Discordant voltage on EKG with the magnitude of myocardial thickness on echocardiography. LVH pattern and history of hypertension should accompany a patient with compensatory LVH on echocardiography, defined usually as >11mm for mild and >17mm for severe.
- If there is LVH pattern on EKG, but no history of hypertension or aortic stenosis, suspicion should be given to HCM. HCM can present with asymmetric thickening on echo, which could be seen as thin "dagger" Q waves on inferior-lateral leads for the classic septal variant or diffuse T wave inversions in the apical variant on EKG. The end diastolic LV diameter should be <45 mm and LV wall thickness ≥13mm in patients with HCM. Young athletes may have thickened LV walls to compensate for their level of physical activity. However, their end diastolic LV diameter should be >55mm, and their LV wall thickness, <13mm. In obstructive variants of HCM, there is late systolic obstruction of the LVOT due to systolic anterior motion of the mitral valve apparatus (Figure 2.60a, Video 2.22). This can be seen as late systolic peaks via CWD of the LVOT on an A5C window (Figure 2.60b).

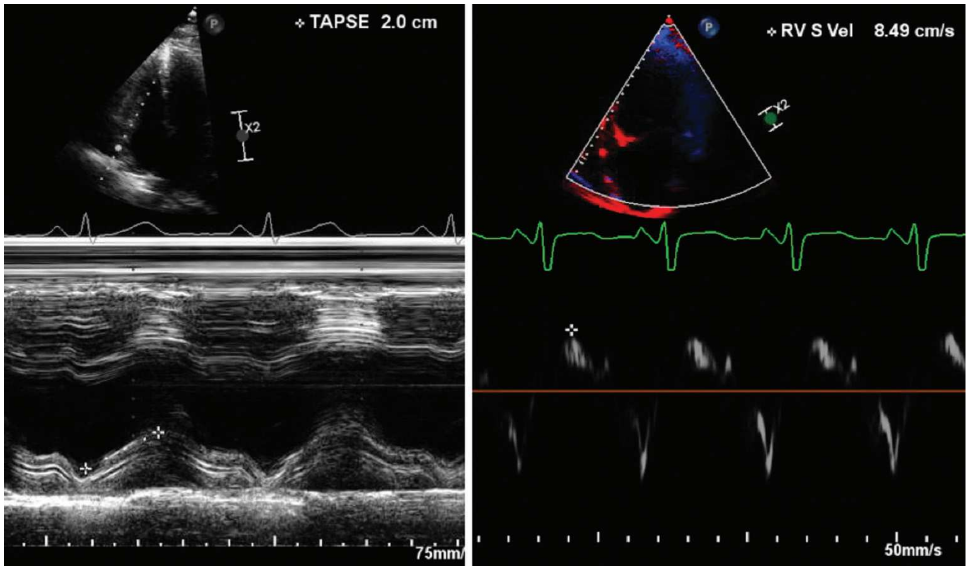

Figure 2.59 **Tricuspid annular plane systolic excursion and S' of tricuspid lateral annulus to estimate right ventricular systolic function.** *Images courtesy of Drs. Anthony Koppula, MD, and Robin Wachsner, MD, Division of Cardiology, Department of Medicine, Olive View–UCLA Medical Center, Los Angeles, CA.*

(a)

(b)

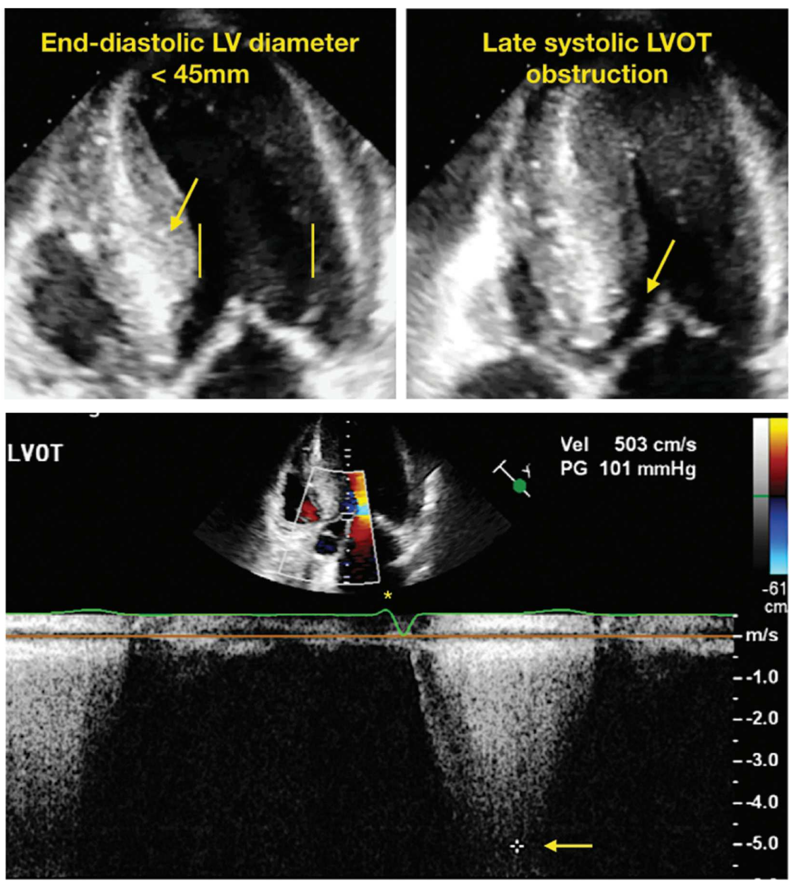

Figure 2.60 (a) **Hypertrophic cardiomyopathy on apical 4-chamber window.** On the left image, the end-diastolic left ventricular diameter is narrow (<45 mm) as there is asymmetric thickening of the septal wall (arrow). On the right image, there is a narrowing of the left ventricular outflow tract (LVOT) due to anterior motion of the mitral valve, causing a characteristic late systolic LVOT obstruction. *Images courtesy of Drs. Anthony Koppula, MD, and Robin Wachsner, MD, Division of Cardiology, Department of Medicine, Olive View–UCLA Medical Center, Los Angeles, CA.* (b) **Continuous wave Doppler of late systolic obstruction due to hypertrophic cardiomyopathy.** Note that there is a delay from the initiation of systole on the electrocardiogram tracing (*) and the acceleration of flow noted by the late systolic peak with a V_{max} of 5 m/s. *Images courtesy of Drs. Anthony Koppula, MD, and Robin Wachsner, MD, Division of Cardiology, Department of Medicine, Olive View–UCLA Medical Center, Los Angeles, CA.*

- When the EKG shows low voltage and/or presence of arrhythmia, amyloidosis or sarcoidosis may be considered. Amyloidosis is a group of disorders that feature fibrillar protein deposits into the myocardium, whereas sarcoidosis is characterized by granulomatous deposition of the myocardium. Amyloidosis on echocardiography is characterized by diffuse LV and RV wall thickening with increased areas of echogenicity, as seen in Figure 2.21 and Video 2.17. This has been described as "granular sparkling." Sarcoidosis on echocardiography is characterized by regional wall involvement, such as thinning and RWMA. However, cardiac sarcoidosis has a highly variable appearance on echo.
- Diastolic dysfunction is a key early finding in HCM, amyloidosis, and sarcoidosis. In particular, a restrictive pattern with low e' velocities should increase suspicion.

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Keywords/Tags: Amyloidosis, infiltrative cardiomyopathy, diastolic dysfunction, systolic dysfunction, congestive heart failure, granular sparkling, echocardiography

> **Learning Point 30:** Hypertrophic and infiltrative cardiomyopathies may have similar appearances on 2D echo. Diastolic assessment and EKG findings may help to differentiate these entities from LVH and athletes' hearts.

31. EXPLANATION

LV aneurysms occur in about 5% to 15% of patients after a transmural MI. They occur as the infarcted myocardium remodels over several weeks to months to fibrotic tissue. The fibrotic tissue, in turn, thins and starts to bulge outward, with no motion in diastole or systole. This patient has an anterior LV aneurysm, as seen in this A3C view (Figure 2.23, Video 2.18). The chronicity of the ST-elevation on EKG is also suggested by the Q waves in the same distribution. However, when the presentation is concerning or questionable, emergent cardiology consultation is suggested, as there are reported cases of acute MI occurring in patients with a history of LV aneurysm.

LV aneurysms must be differentiated from pseudoaneurysms, which are due to rupture of a weakened, infarcted segment of the LV wall, usually days to weeks after a MI. While there are no reliable data, it is thought that the vast majority of cardiac ruptures lead to a hemorrhagic pericardial effusion and resultant death from tamponade. However, if the rupture is contained within a focal area of the pericardial sac, patients are typically hemodynamic stable. Pseudoaneurysms are typically located in the inferior or posterior pericardium, as opposed to the anterior location of most aneurysms. TTE can be used to make the diagnosis (Figure 2.61a), and it is then confirmed under ventriculogram. Surgical resection often leads to a good prognosis, so emergent cardiothoracic surgery consultation is warranted when the diagnosis is confirmed.

There is no evidence of an LV thrombus, although large LV aneurysms, especially those involving the apex, are associated with thrombi formation due to the turbulent flow in these regions. While large thrombi may be easily visualized, more subtle thrombi can be diagnosed using echo contrast, TEE, or cardiac MRI (Figure 2.61b).

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Keywords/Tags: Left ventricular aneurysm, LV thrombus, LV pseudoaneurysm

> **Learning Point 31:** LV aneurysms occur over a period of weeks to months from cardiac remodeling after an MI. LV pseudoaneurysms occur as a result of LV wall rupture days after an MI.

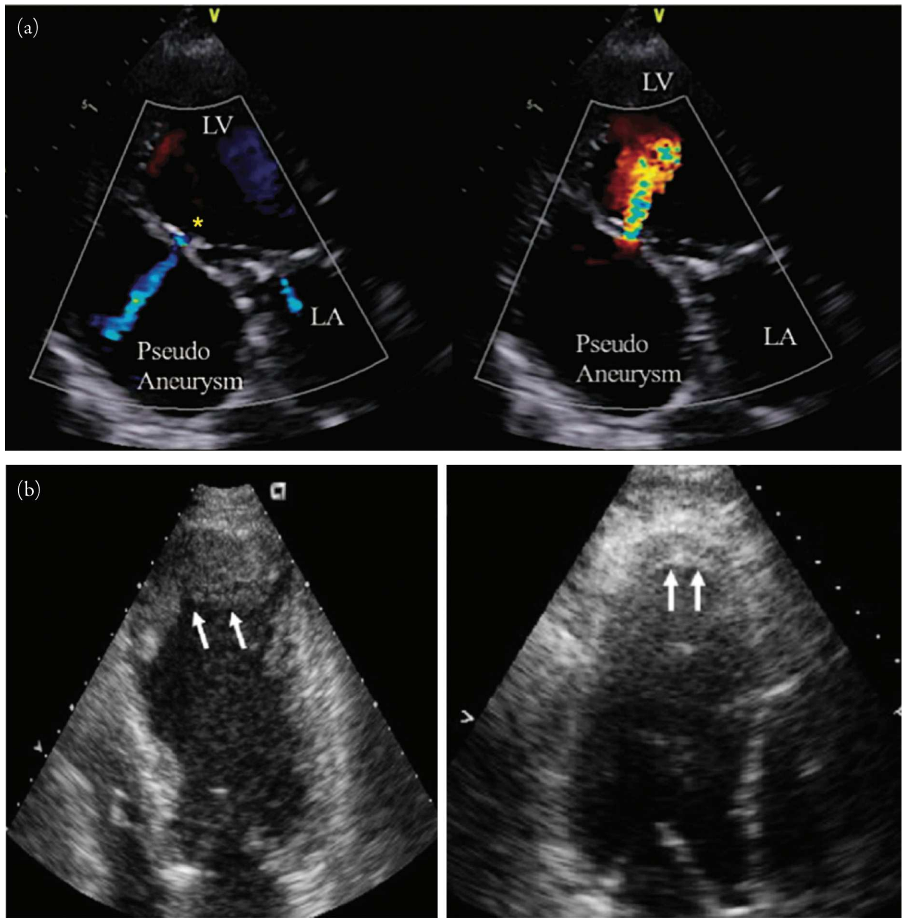

Figure 2.61 (a) **Ventricular pseudoaneurysm**. Note that the neck (*) of a left ventricular (LV) pseudoaneurysm is narrow compared to that of a LV aneurysm. From Figure 1C and 1E of Shimono H, Kajiya T, Atsuchi Y, Atsuchi N, Ohishi M. Giant left ventricular pseudo-aneurysm after posterior myocardial infarction. *Euro Heart J.* 2018;39(37):3479. (b) **Apical thrombi.** The image on the left shows a large and readily visualized left ventricular thrombus, while the image on the right shows a more subtle thrombus that may require echo contrast, transesophageal echocardiography, or cardiac magnetic resonance imaging to confirm. Adapted from Figure 2 of Srichai MB, Junor C, Rodriguez LL, et al. Clinical, imaging, and pathological characteristics of left ventricular thrombus: a comparison of contrast-enhanced magnetic resonance imaging, transthoracic echocardiography, and transesophageal echocardiography with surgical or pathological validation. *Am Heart J.* 2006;152(1):75–84.

32. EXPLANATION

B. Diastolic dysfunction. The ischemic cascade is a fundamental concept in acute coronary syndromes and, in particular, to unstable angina (Figure 2.62). It describes the classic pathophysiology of the effect of ischemia to myocardium. First, as the evolving plaque causes arterial obstruction to the affected myocardium, there is flow redistribution to healthy myocardium. As a result, there is decreasing oxygen and energy substrate to the affected myocardium, which leads first to impaired relaxation. Remember that impaired relaxation is a very active process, depending on ATP to unbind the contracted actin–myosin chain, which allows for expansion or relaxation in diastole. This is why diastolic dysfunction precedes systolic dysfunction, which is seen as regional wall motion abnormality of the affected territory. Lastly, EKG changes occur, followed by symptoms, and if the ischemia is not improved, there is MI. Note that "silent ischemia" occurs when the level and timing of the ischemic

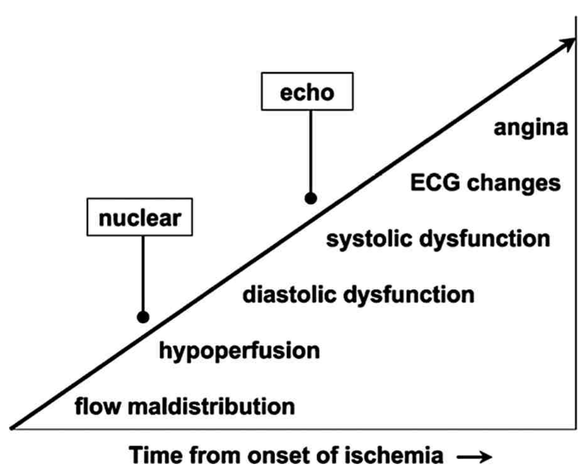

Figure 2.62 **The ischemic cascade.** From Figure 1 of Schinkel AF, Bax JJ, Geleijnse ML Noninvasive evaluation of ischaemic heart disease: myocardial perfusion imaging or stress echocardiography? *Eur Heart J.* 2003;24(9):789–800.

insult is early or not severe enough to produce classic symptoms in acute coronary syndrome. This is the basis for stress testing, in which myocardial perfusion imaging has the highest sensitivity—as it detects fixed and reversible perfusion defects—followed by echocardiographic findings, and, last, exercise treadmill testing.

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Keywords/Tags: ischemic cascade, impaired relaxation, stress testing

Learning Point 32: The ischemic cascade allows for understanding of advantages and disadvantages to various imaging modalities in acute coronary syndrome.

33. EXPLANATION

D. Both B and C. Aortic stenosis occurs with bicuspid aortic valve (BAV), age-related calcifications, and rheumatic heart disease. Aortic stenosis in the setting of native or prosthetic valve dysfunction can be evaluated using the dimensionless index, which has the benefit of removing the variability in LVOT diameter measurements (Figure 2.63a).

The dimensionless index reflects the effective valvular area in proportion to the cross-sectional area across the LVOT by taking the ratio of the peak velocities (in m/s) across the LVOT and aortic jet past the stenotic valve, respectively. A ratio <0.25 m/s is significantly abnormal and indicates severe aortic stenosis. A3C or A5C views can be used, with color Doppler applied over the aortic outflow tract to assess for stenotic flow. For quantification, PWD is used over the LVOT, while CWD is used to evaluate flow through the aortic valve. A graph demonstrating velocity (in m/s) versus time (seconds) is formed, respectively, and the peak velocities can be traced out for the formal calculation. Normal aortic jet velocity is >2.5 m/s, while >4 m/s suggests severe aortic stenosis. In addition, the shape of the aortic jet velocity curve alludes to the degree of obstruction. A more rounded velocity curve implies severe obstruction where peak velocity across the aortic valve occurs later in systole, while a normal to mild degree of stenosis generates a triangular curve (Figure 2.63b).

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Keywords/Tags: Aortic stenosis, valvular heart disease, continuous wave Doppler, pulse wave Doppler, Doppler echocardiography, dimensionless index

Learning Point 33: Artificial valve malfunction can be assessed using a dimensionless valve index (DVI).

34. EXPLANATION

D. Both A and B. This patient's echo shows evidence of Ebstein's anomaly, which is apical displacement of the tricuspid valve, commonly referred to as "atrialization of the RV." This leads to a failure of the tricuspid leaflets to coapt, thus leading to significant tricuspid regurgitation, RA enlargement, and arrhythmias. The classic case of EA is severe tricuspid regurgitation with right-to-left shunt via an ASD (80%–95% of EA patients have ASD), thus leading to a cyanotic young child. However, milder forms of EA with less severe tricuspid regurgitation can be diagnosed in adulthood with relatively little cyanosis. Surgery is indicated when there are refractory symptoms like persistent arrhythmias or right-sided congestive heart failure, but adults with mild forms of EA can expect normal lifespans (Figure 2.24).

ASDs are one of the most common congenital heart conditions, affecting about 0.1% of the population. There are many types of ASDs, with the most common being secundum defects (Figure 2.64). There is typically a left-to-right shunt leading to RA and RV dilation and, if advanced, pHTN. ASD closure can be performed via transcatheter approach and is indicated if the ASD diameter is >10mm and there is presence of RV/RA dilation and/or significant left-to-right shunt.

There are 2 forms of TGA. In the dextro (D-TGA) form, the RV is connected to the aorta, while the LV is connected to the pulmonary trunk. A patent ductus arteriosus

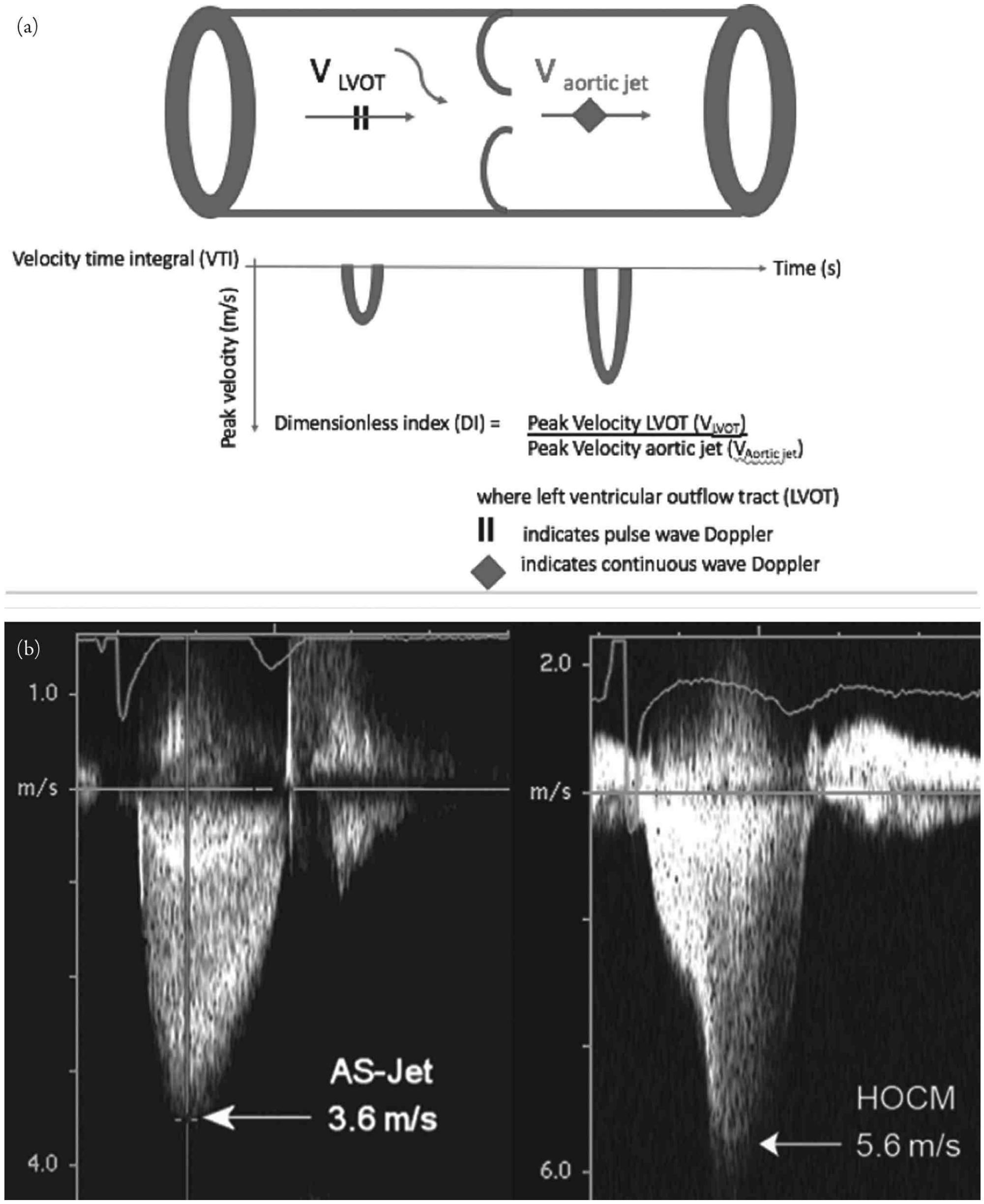

Figure 2.63 (a) **Dimensionless index.** (b) **Aortic stenosis and sub-aortic stenosis jets.** From Figure 3 of Baumgartner H, Hung J, Bermejo J, et al.; American Society of Echocardiography; European Association of Echocardiography. Echocardiographic assessment of valve stenosis: EAE/ASE recommendations for clinical practice. *J Am Soc Echocardiogr*. 2008;22(1):1–23.

or balloon septostomy is required to stabilize the newborn, followed by surgical repair. In the levo (L-TGA) form, the transposition occurs as RA–LV–PA and LA–RV–aorta. Patients with L-TGA can survive until adulthood, with many developing systolic heart failure, both due to aortic insufficiency as well as RV dysfunction (see Figure 2.65).

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Keywords/Tags: TGA, EA, ASD

Learning Point 34: Ebstein's anomaly (EA) is characterized by apical displacement of the tricuspid valve, leading to "atrialization" of the RV.

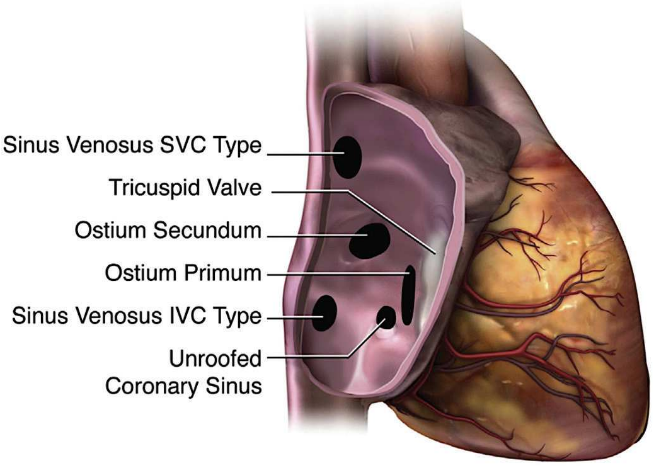

Figure 2.64 **Atrial septal defects.** From Figure 1 of Silvestry FE, Cohen MS, Armsby LB, et al.; American Society of Echocardiography; Society for Cardiac Angiography and Interventions. Guidelines for the echocardiographic assessment of atrial septal defect and patent foramen ovale: from the American Society of Echocardiography and Society for Cardiac Angiography and Interventions. *J Am Soc Echocardiogr.* 2015;28:910–958.

35. EXPLANATION

B. BAV. BAV is a congenital defect that is occasionally found in adulthood. It affects 1% to 2% of the population and is more common in males. It most often results from a fusion of the right and left coronary leaflets. On POCUS echo, there may be aortic insufficiency on color Doppler as well as doming of the anterior cusp, as seen on the TEE mid-esophageal long axis view in Figure 2.25b. BAV is asymptomatic in some patients but is associated with aortic coarctation in at least 25% of patients. Patients with BAV have a higher risk of development of aortic aneurysm or dissection due to eccentric outflow generated by the abnormal valve as well as a deficiency in fibrillin-1 protein in the aorta wall that predisposes to dilation. In a 25-year longitudinal study, 25% of patients with BAV developed aortic aneurysms, while 1.3% developed aortic dissection (which is 8 times higher than a similar cohort without BAV).

In patients who are symptomatic with a BAV, evaluation should include evidence of worsening thoracic aortic aneurysm or dissection. In patients who are asymptomatic, the presence of hemodynamic alterations due to BAV, along with a thoracic aorta diameter >40 mm, should prompt referral to cardiothoracic surgery for evaluation for surgical repair of the valve and aortic aneurysm.

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Keywords/Tags: BAV, aortic dissection, aortic aneurysm

Learning Point 35: BAV affects 1% to 2% of the population and is associated with early aortic valve degeneration as well as aortic aneurysms and dissections.

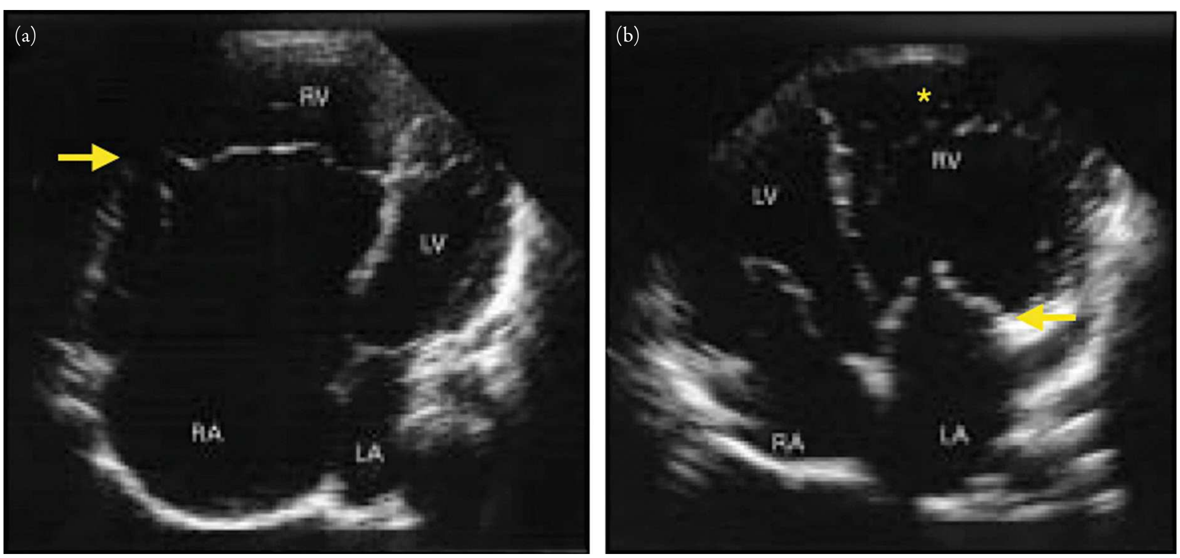

Figure 2.65 **Congenital heart disease in adults.** Panel A shows Ebstein's anomaly, with atrialization of the right ventricle (arrow), enlarged right atria, as well as evidence of atrial septal defect. Panel B shows a patient with levo-transposition of the great arteries, in which the right atria is connected to the left ventricle, and the left atria to the right ventricle (RV). Findings to identify the RV include the tricuspid valve (arrow) is normally more apically displaced than the mitral valve and the presence of trabecular tissue (*) at the apex of the RV. Adapted from Figures 25 and 26 of Houston A, Hillis S, Lilley S, Richens T, Swan L. Echocardiography in adult congenital heart disease. *Heart.* 1998;80(Supp 1):S12–S26.

36. EXPLANATION

D. A and C. A PFO is a conduit for clot passage to the brain and may be a facilitator in a portion of patients diagnosed with cryptogenic stroke, especially affecting young stroke patients. AFib has a well-known association with cardioembolic stroke, and the presence of concomitant PFO may increase risk. A PFO causes blood to leak from the right atrium to the left and is asymptomatic in the estimated 25% of the population with a PFO. However, it may allow small blood clots that would normally be filtered through the lung to bypass the pulmonary and enter the systemic circulation. The increased use of bubble studies (echo contrast with TEE) in CVA evaluation has established a 4-fold risk of CVA in patients with PFO as compared to those without PFO (see Figure 2.49 and Video 2.23). If associated with a stroke, treatment options vary from aspirin therapy, anticoagulation, transcatheter closure devices, or closure through surgery.

Ventricular septal defects are the 2nd most common congenital heart condition after BAV, with about 1 in 300 affected. They can be divided into muscular or membranous types and are associated with Eisenmenger syndrome, conduction defects, and endocarditis (Figure 2.66, Video 2.24). In isolation, they are rarely associated with cardioembolic stroke; however, complications like endocarditis and R→L shunting in Eisenmenger syndrome may increase this risk.

Spontaneous echo contrast is a swirling appearance visualized in either dilated chambers such as the LV or LA and signifies a low flow state (Figure 2.67, Videos 2.25a and 2.25b). It is due to increased backscatter of relatively stagnate RBCs. Spontaneous echo contrast is associated with a 4-fold risk of CVA in nonvalvular AFib patients, as well as about a 10% risk of CVA per year.

(a)

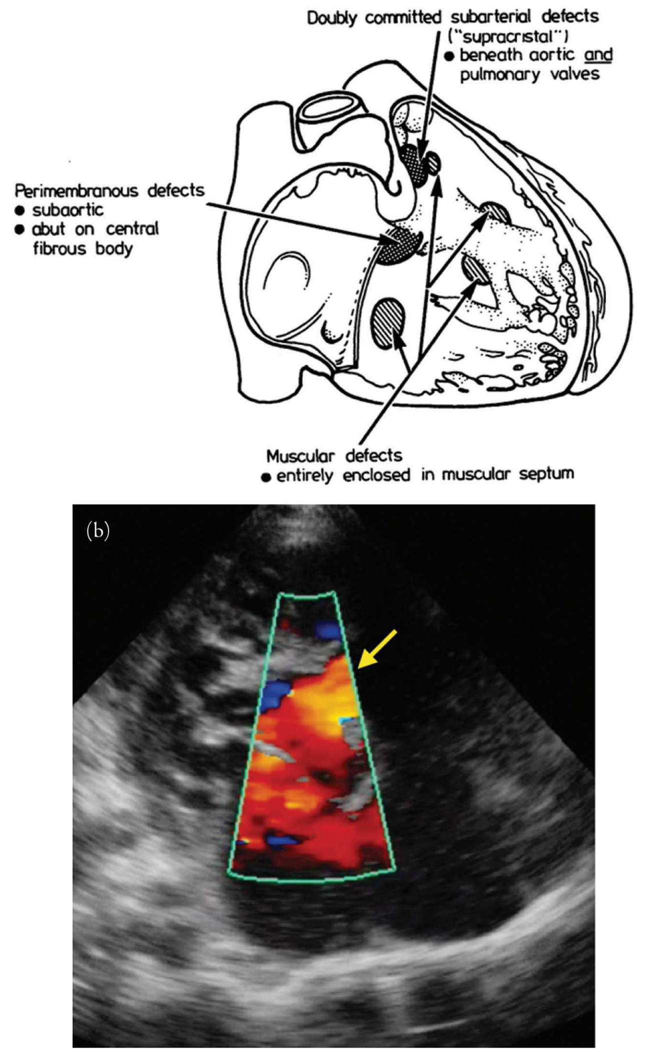

Figure 2.66 (a) **Ventricular septal defect types.** From Figure 2 of Sutherland G, Godman MJ, Smallhorn JF, Guiterras P, Anderson RH, Hunter S. Ventricular septal defects: 2D echocardiographic and morphological correlations. *Br Heart J.* 1982;47:316–328. (b) **Ventricular septal defect on apical 4-chamber window.** Color Doppler shows flow going right-to-left, suggestive of Eisenmenger syndrome.

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Keywords/Tags: PFO, spontaneous echo contrast, Eisenmenger syndrome, VSD, BAV

Learning Point 36: PFO is associated with cryptogenic stroke. It can be assessed using echo contrast and a Valsalva maneuver.

37. EXPLANATION

D. A and C. This patient most likely has tuberculosis, which can lead to an infiltrative cardiomyopathy and as well as constrictive pericarditis. These 2 entities can have overlapping etiologies and clinical presentation and thus can be difficult to differentiate. On exam, both may show evidence of systemic congestion as well as dilated IVCs. Typically, constrictive pericarditis will not exhibit pulmonary congestion, as detailed in the following description.

Constrictive pericarditis is caused by inflammation and thickening of the fibrous pericardium, leading to impaired

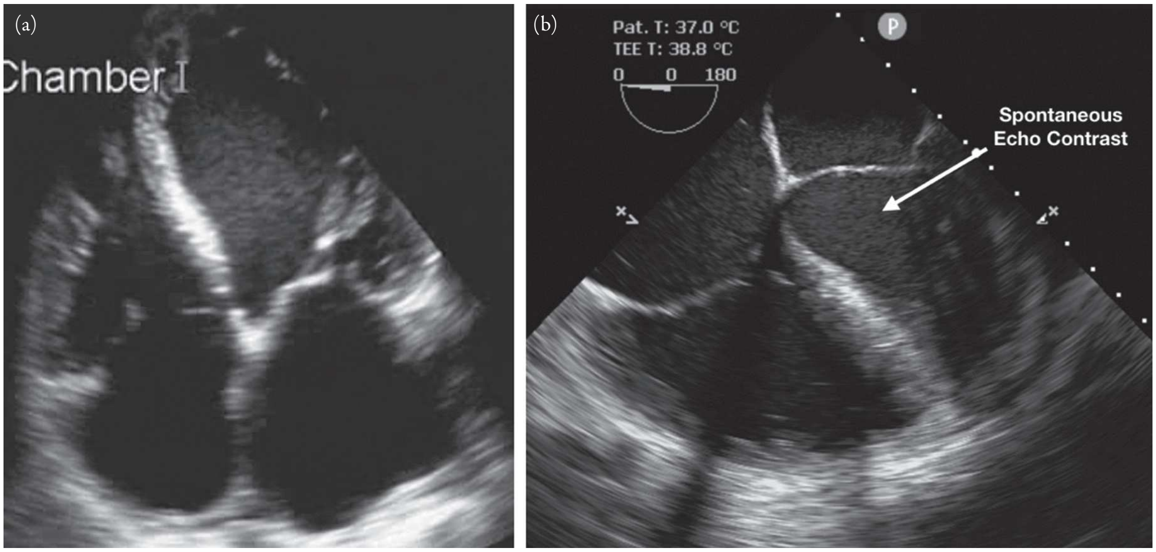

Figure 2.67 **Spontaneous echo contrast in the left ventricle on an apical 4-chamber window (a) and on transesophageal echocardiography (b).**

filling of both the right and left heart. As a result, it can lead to tamponade physiology without a pericardial effusion. On an apical window, the septal wall can appear to shift due to ventricular interdependence (Figure 2.68). This is described as a "septal bounce." On TDI, the lateral annulus e' normally is higher than the septal annulus e', as the septal wall tethers the mitral valve, leading to restricted motion. In constrictive pericarditis, the lateral annulus motion is restricted by inflammation and thickening of the pericardial sac. Therefore, the septal annulus moves faster than the lateral annulus, which is referred to as "annulus reversus" or "annulus paradoxus."

Restrictive cardiomyopathies typically lead to diastolic impairment prior to chamber dilation and systolic dysfunction. TDI of the mitral annulus in restrictive cardiomyopathies will show depressed e' velocities at both the lateral and septal annuli. See Figure 2.69.

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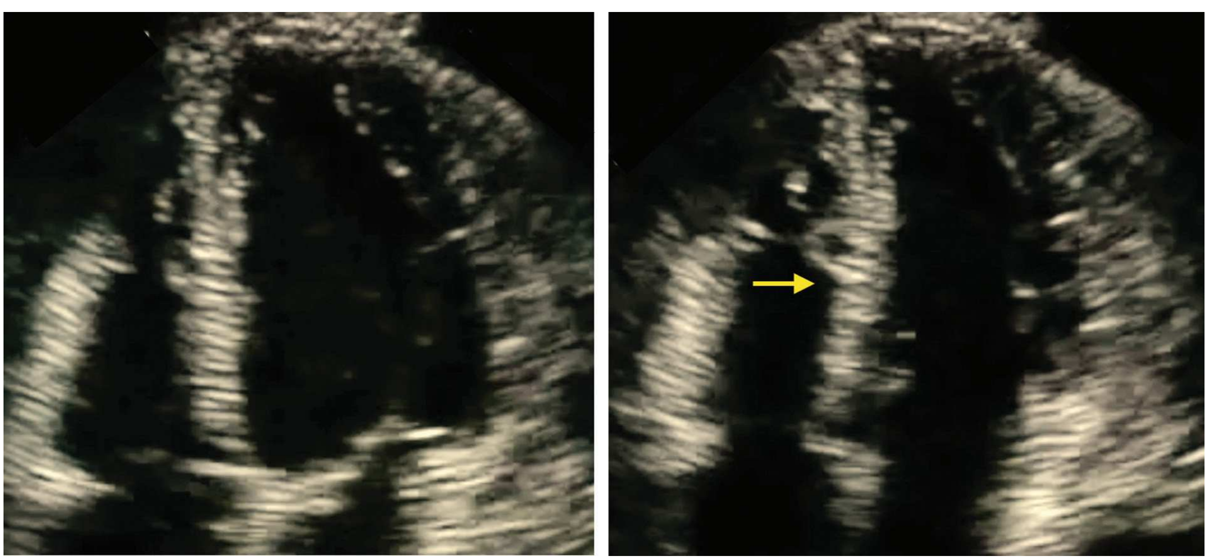

Figure 2.68 **Septal bounce in constrictive pericarditis.** From Video 7.2 of Saric M, Kronzon I. Doppler and hemodynamics. In: Klein AL, Asher CR, eds. *Clinical Echocardiography Review: A Self-Assessment.* 1st ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2011:79–121.

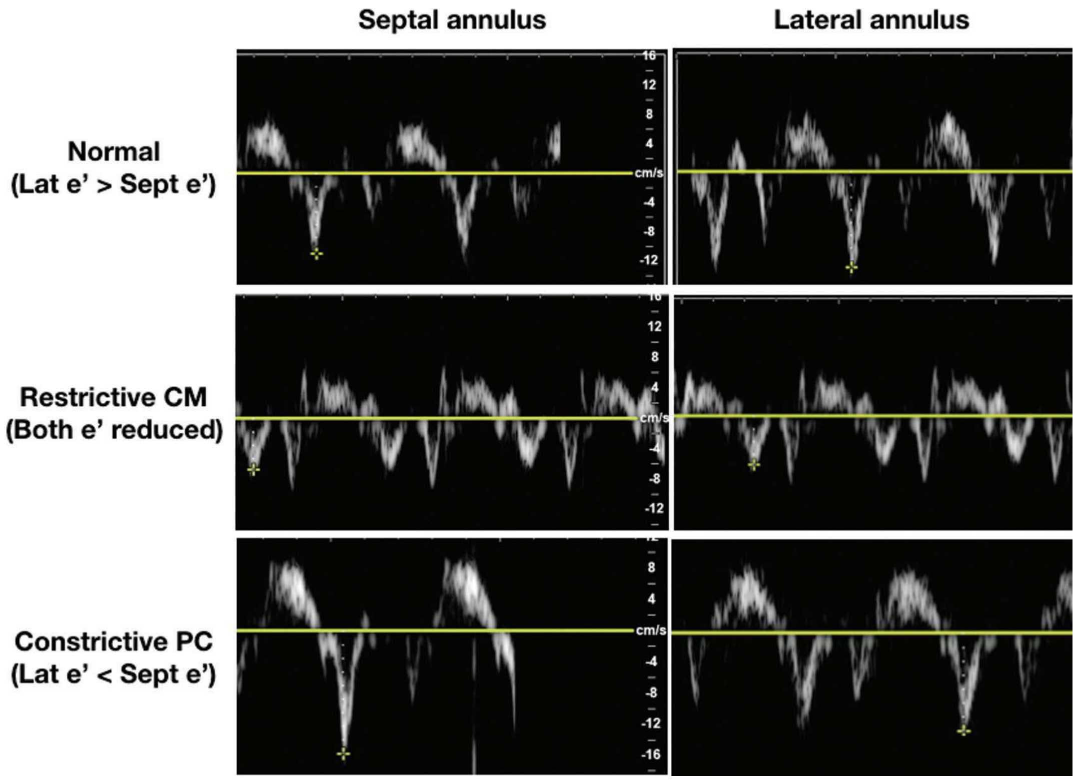

Figure 2.69 **Tissue Doppler imaging in restrictive cardiomyopathy and constrictive pericarditis.** Normally, lateral e' velocity is greater than septal e', due to tethering of the septal annulus to the septal wall. In restrictive cardiomyopathies, the e' velocities at both septal and lateral annuli are decreased. In constrictive pericarditis, the septal e' exceeds lateral e', due to inflammation and thickening of the pericardial sac, which slows movement of the left ventricular lateral wall.

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Keywords/Tags: Constrictive pericarditis, restrictive cardiomyopathy, congestive heart failure, tissue doppler imaging, mitral annulus velocity

Learning Point 37: Constrictive pericarditis leads to impairment in both right and left sided filling, similar to pericardial tamponade but without any effusion. On A4C window, the pericardium appears more hyperechoic and thickened, and there is a characteristic septal bounce. TDI can be used to differentiate constrictive pericarditis from restrictive cardiomyopathies.

38. EXPLANATION

D. Parasternal short axis—tilt the probe scan plane inferiorly to avoid a false-positive D-shaped LV. This is a parasternal short axis window that is showing what appears to be a dilated RV with flat IVS. However, the scan plane is not perpendicular to the imaged structures, but rather an oblique plane that is between the short axis and an apical window. For this reason, the RV appears to be enlarged and the septum, flat, since in an A4C window, the RV is larger and the septum appears linear as compared to a parasternal short axis window. Note the appearance of the RV moderator band, seen as a horizontal linear structure just deep to the RV free wall. This should not be seen on a true parasternal short axis window, as the moderator band is located near the apex.

To confirm RV dilatation and septal flattening, tilt the probe so that the scan plane is pointed more apically or inferiorly to image a more perpendicular plane (Figure 2.70, Video 2.27). If the RV appears smaller and the septum rounds out, then there is no RV strain. If the RV continues to be dilated and the septum is flat, then RV strain is the likely diagnosis. In general, tilting in parasternal short axis to visualize all levels is *not* recommended due to the many oblique planes generated. Instead, sliding from base to apex in a plane perpendicular to the imaged structures is recommended.

Apical foreshortening is also a common problem, as it leads to a falsely thickened LV and, thus, estimates of systolic function. It occurs when the scan plane is oriented obliquely, from the anterior apex to the posterior wall of the atria (Figure 2.71). Often, the atria look small, while the apical myocardium appears as thick or even thicker than the septal and lateral myocardium. Normally, the apical myocardium is thin compared to these walls.

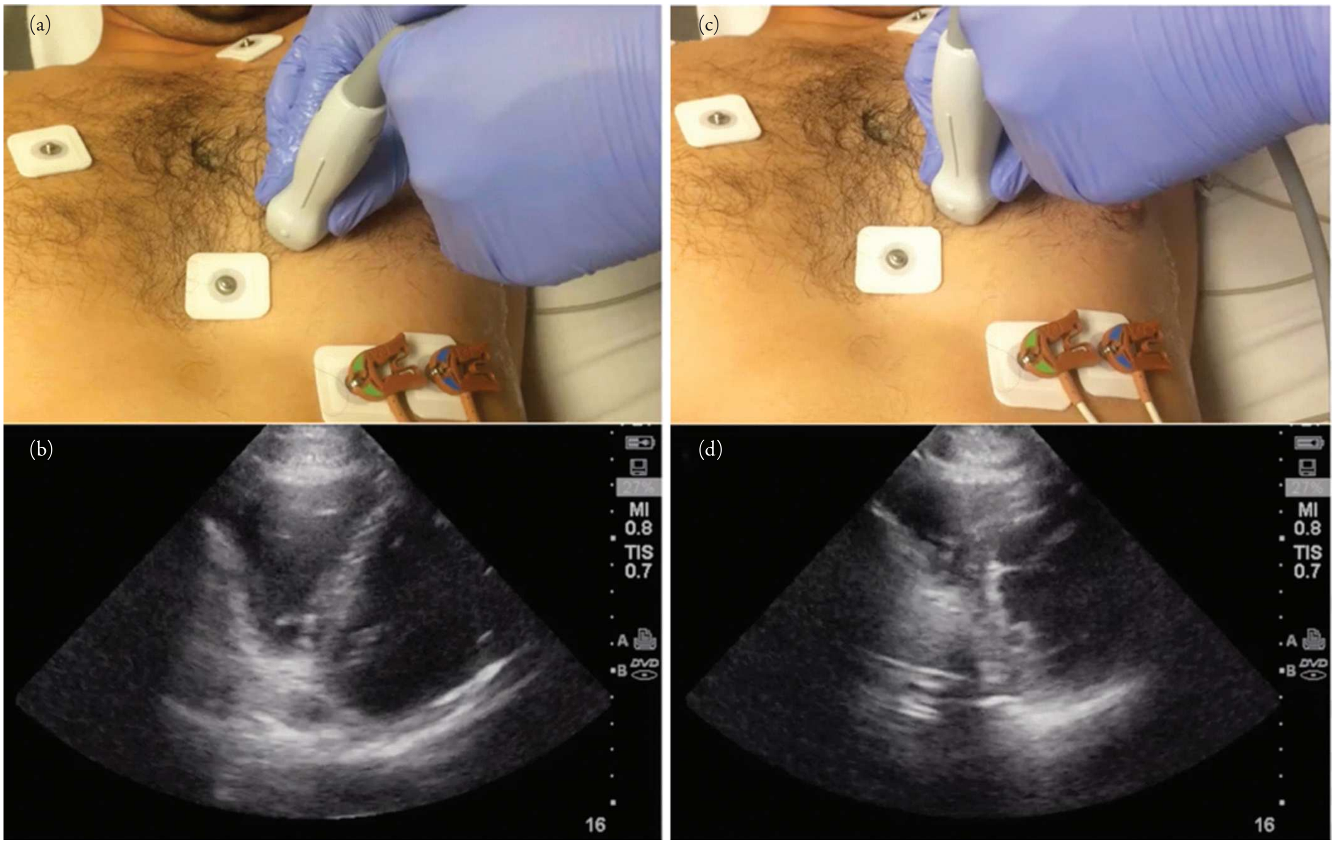

Figure 2.70 **Avoiding a false "D-shaped" left ventricle by tilting the scan plane inferiorly.** Panel A shows improper tilt position that is too superior causing an oblique plane and appearance of the false D sign in Panel B. Panel C shows proper transducer placement with more inferior tilt and perpendicular plane to the heart showing a circular left ventricle in Panel D.

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Keywords/Tags: apical foreshortening, false positive D-shaped left ventricle

Learning Point 38: Foreshortening occurs when the apical plane cuts through the ventricle just anterior or posterior to the apex. It results in both inaccurate measurement of the LV chamber and may result in a false-positive D-shaped LV septum.

39. EXPLANATION

C. Rotate the probe to identify the true long axis. This is a parasternal long axis view in which the sonographic plane is not in line with the true long axis of the heart. To obtain the true long axis, rotate the probe either clockwise or counterclockwise to "stretch out" the LV on the ultrasound image. Once the LV is maximally lengthened, the probe indicator is now pointed toward the cardiac apex, and the imaginary line from the probe to the apex denotes the LV long axis. Note that the traditional teaching that "the apex is under the nipple or inframammary fold," does not usually correlate with individual patient anatomy. See Figure 2.72 and Video 2.28.

Often the long axis may be visualized, but not in a plane at the center of the LV chamber. This will be apparent as trabecular tissue will be seen as opposed to leaflet tips of the mitral and aortic valves. Tilting or fanning the probe will help to obtain a central plane. See Figure 2.73.

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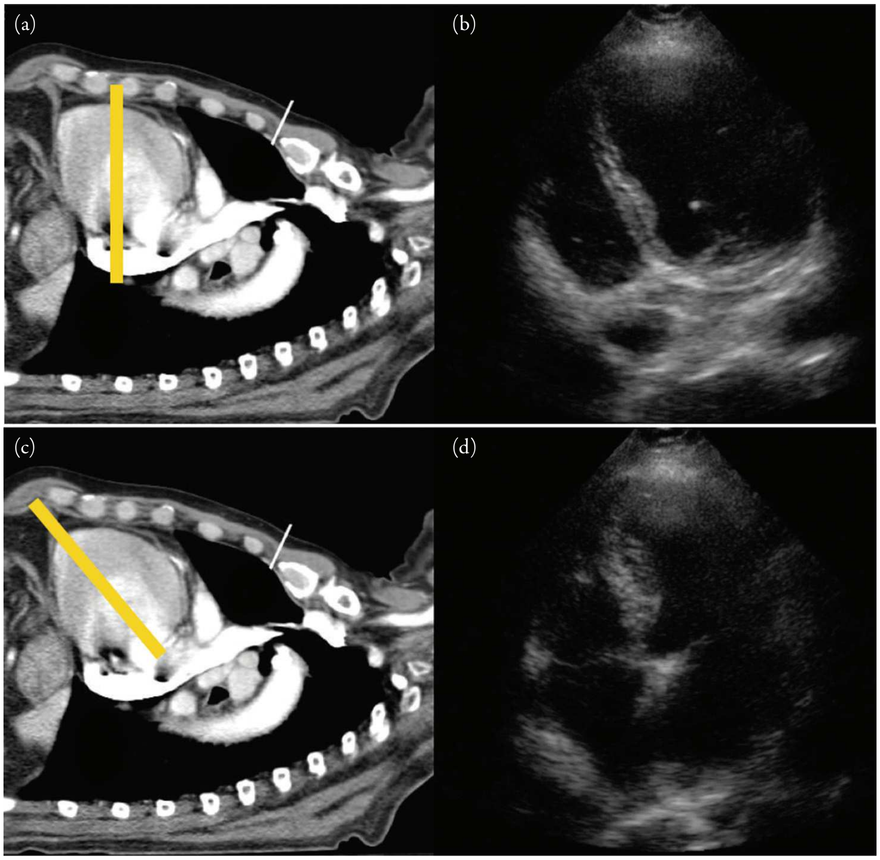

Figure 2.71 **Avoiding apical foreshortening.** Panels (a) and (b) show foreshortening, while panels (c) and (d) show a true apical window.

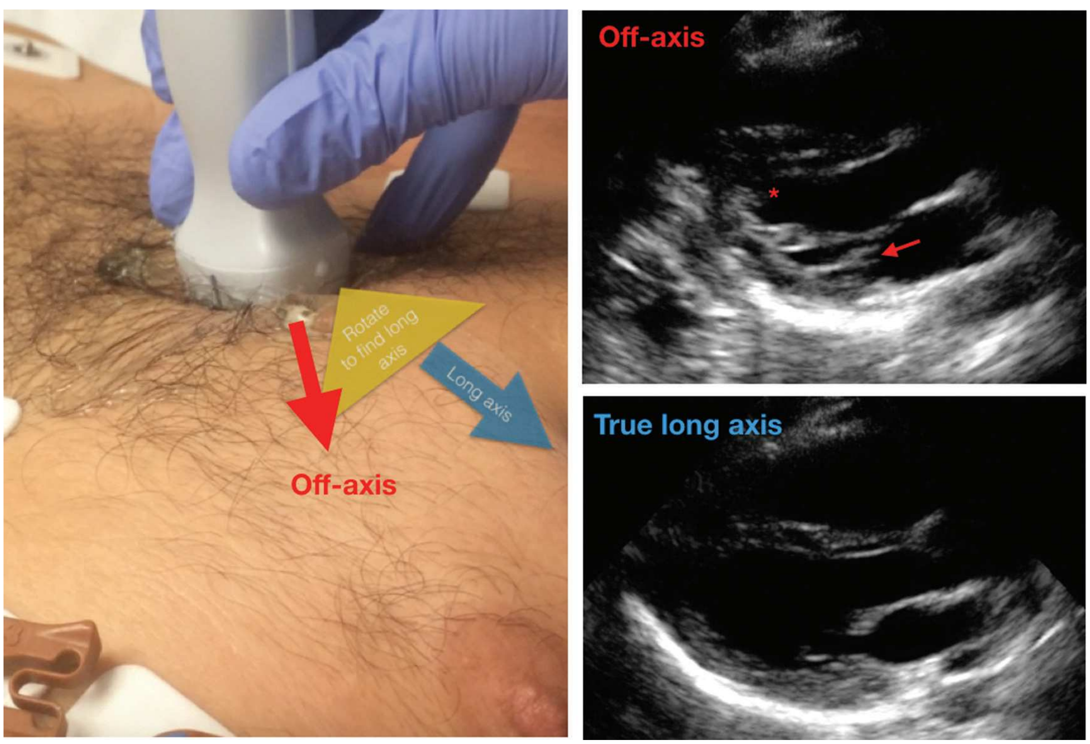

Figure 2.72 **Rotating scan plane to find the true parasternal long axis.** Note that in this patient, with the indicator pointed inferior to the nipple, the plane is off-axis. This is apparent as the left ventricle (LV) chamber appears rounded (*), and there is abundant papillary and chordal tissue seen (arrow). By slowing rotating the probe in either clockwise or counterclockwise direction, the image on the screen will either show the LV elongating or progressing to a short axis view. By rotating in the direction of LV elongation, a true long axis is obtained.

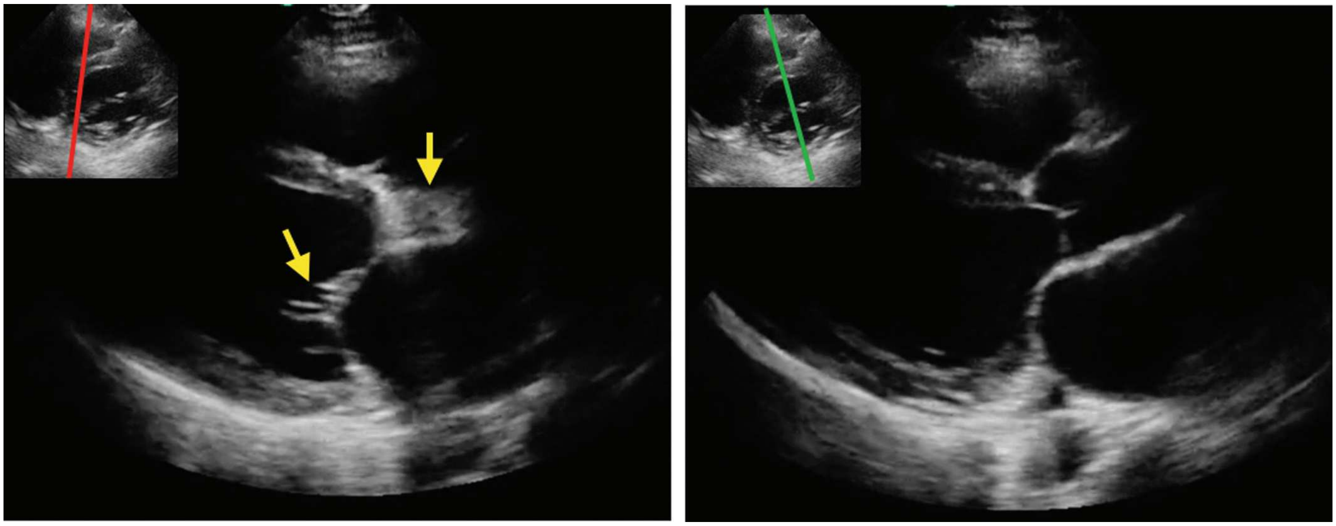

Figure 2.73 **Tilting to find a central plane on parasternal long axis.** On the left, the plane (red line) is medial to the center of the LV. As a result, chordal tissue and septal parts of the aortic outflow tract (arrows) are imaged. The image on the right shows a central plane (green line), which shows both the mitral leaflets and aortic cusps in view.

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Keywords/Tags: parasternal long axis, tilting, rotating

Learning Point 39: Once an adequate intercostal space is found that is free of bone and air artifact, rotation and tilting of the probe can optimize a parasternal long axis view.

40. EXPLANATION

D. All of the above. TOF is associated with subpulmonic stenosis, VSD, RV hypertrophy, and an overriding aortic arch (Figure 2.74a). Due to the subpulmonic stenosis, patients have high RVSP but low pulmonary arterial pressure. PAT should, therefore, be normal, or >100ms. However, many TOF patients after repair may develop pHTN for several reasons, including pulmonary vasculature hypoplasia, a pre-existing large left-to-right shunt, and aortic-pulmonary collaterals. TOF patients typically have a large perimembranous VSD that leads to equalization of pressures between the LV and RV. Therefore, the VSD in TOF leads to the faintest, if audible, of murmurs. When there is a decrease in right-sided pressures (such as due to dehydration), there is worsening of the subpulmonic stenosis, leading to intensification of a crescendo–decrescendo systolic murmur, as well as development of the classic Tet spells, in which deoxygenated blood is shunted to the systemic circulation via the VSD.

Persistent left subclavian vein (PLSV) occurs in roughly 1 in 250 patients and is usually asymptomatic. It is a failure of the left anterior cardinal vein during development to regress. Instead, the left internal jugular and subclavian veins feed into the PLSV, which itself often feeds into the coronary sinus. It is often diagnosed on thoracic imaging or when there is an attempt to place an AICD or pulmonary artery catheter through the left internal jugular or subclavian veins (Figure 2.74b). The catheter is placed into the PSLV, through the coronary sinus and almost perpendicular to the lateral wall of the right atrium. It is thus difficult to redirect the balloon at such a steep angle into the RV.

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Keywords/Tags: Tetralogy of Fallot, subpulmonic stenosis, VSD, PAT, persistent left subclavian vein

Learning Point 40: Persistent left superior vena cava syndrome affects about 1 in 200 and is typically

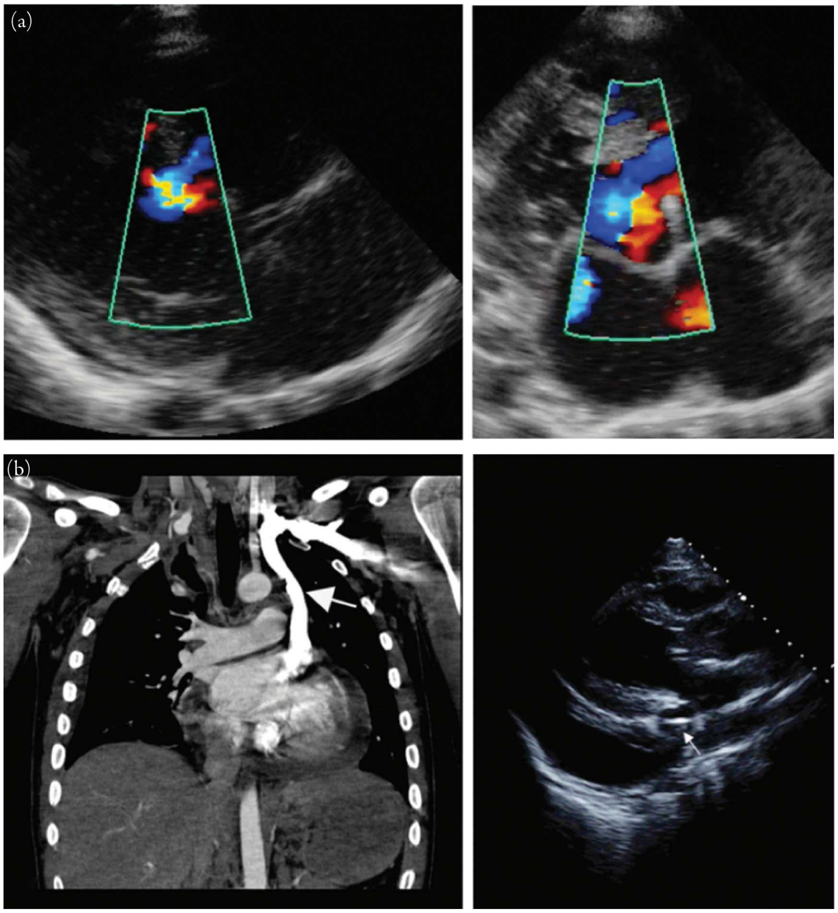

Figure 2.74 (a) **Tetralogy of Fallot.** Ventricular septal defect with color flow Doppler between the 2 ventricles on parasternal long axis (left) and apical 4-chamber (right) view. (b) **Persistent left superior vena cava.** Left panel: CT showing L-sided superior vena cava (large arrow). Right panel: Transthoracic echocardiogram showing catheter in the dilated coronary sinus (small arrow). Adapted from Figures 3 and 4 of Goyal S, Punnam SR, Verma G, Ruberg FL. Persistent left superior vena cava: a case report and review of literature. *Cardiovasc Ultrasound.* 2008;6:50.

asymptomatic. It is a failure of regression of the left superior cardinal vein that leads to difficulties in the placement of pulmonary artery catheters as well as cardiac pacemakers.

41. EXPLANATION

C. Mid-esophageal four chamber view. The ultrasound in this case shows a mid-esophageal 4-chamber view using TEE. Active chest compressions can be seen in the media. The American Society of Echocardiography defines a comprehensive TEE exam as obtaining 28 views (Hahn 2013). However, for a focused TEE in the point-of-care setting, a simplified 4-view approach has been suggested (Arntfield 2015). The 4 suggested views are the mid-esophageal 4-chamber (Figure 2.75a, Video 2.29), mid-esophageal long axis (Figure 2.75b, Video 2.30), transgastric short axis (Figure 2.75c, Video 2.31), and bicaval views (Figure 2.75d, Video 2.32). The 4 views can be used to view specific structures and answer focused questions (Table 2.1). Arntfield et al. suggest that a 4-hour training session involving simulation training can be used to help learn these 4 focused TEE views. The main indications for using focused TEE would be in intracardiac arrest care, postcardiac arrest management, and undifferentiated hypotension (Arntfield 2016). The most frequently used and easiest to obtain TEE view is the mid-esophageal 4-chamber view as it usually the first view that is seen during TEE probe insertion and does not require omniplane manipulation of the beam angle. For cardiac arrest the most common views are the mid esophageal 4-chamber view and the mid-esophageal long axis view. Using the mid-esophageal long axis view, compression of the LVOT can also be assessed (Figure 4.38) during

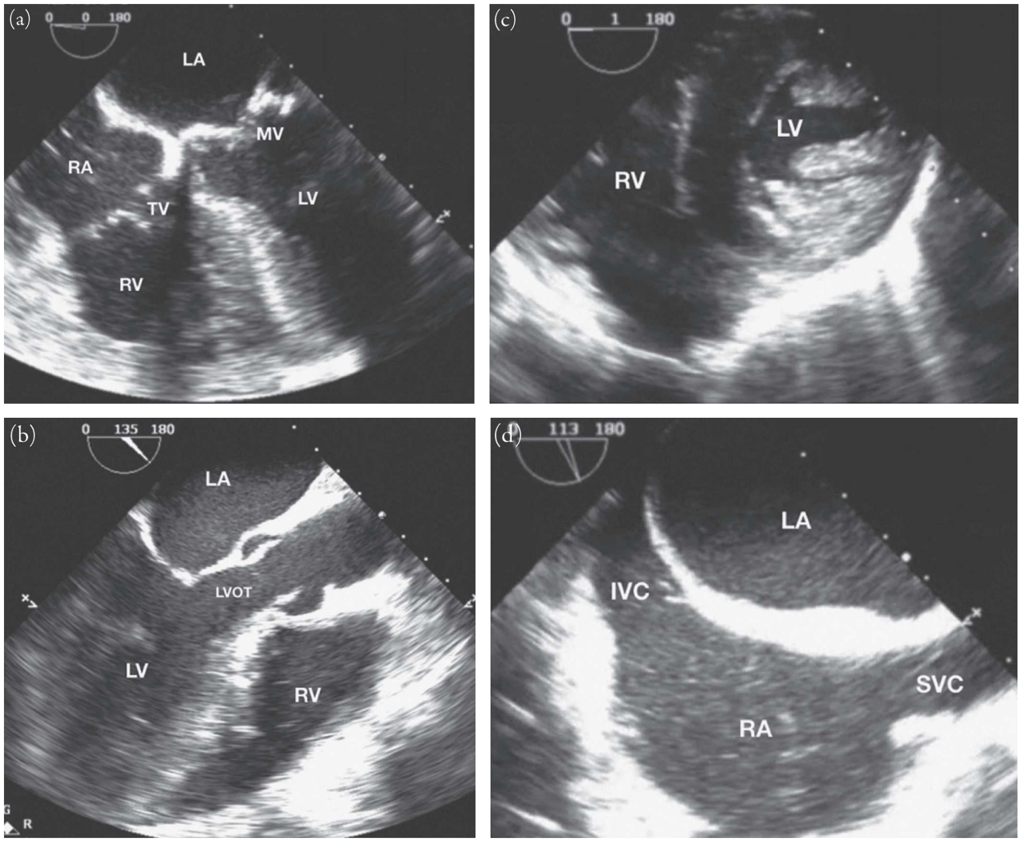

Figure 2.75 (a) **Transesophageal echocardiography, mid-esophageal 4-chamber view.** RA = right atrium; RV = right ventricle; LA = left atrium; LV = left ventricle; TV = tricuspid valve; MV = mitral valve. (b) **Transesophageal echocardiography, mid-esophageal long axis view.** RV = right ventricle; LA = left atrium; LV = left ventricle; LVOT = left ventricular outflow tract. (c) **Transesophageal echocardiography, trans-gastric short axis view.** RV = right ventricle; LV = left ventricle. (d) **Transesophageal echocardiography, bicaval view.** RA = right atrium; LA = left atrium; IVC = inferior vena cava; SVC = superior vena cava.

Table 2.1. FOUR VIEWS OF THE FOCUSED TRANSESOPHAGEAL ECHOCARDIOGRAPHY PROTOCOL

VIEW	LOCATION	TRANSDUCER CONTROLS	STRUCTURES OF INTEREST	TTE EQUIVALENT	QUESTIONS ANSWERED
Mid-esophageal four-chamber view	Mid-esophagus	0^0, neutral flexion	All chamber, valves, and pericardium	Apical 4-chamber	LV and RV functions, mitral/tricuspid valve lesions, pericardial effusion
Mid-esophageal long axis with and without color	Mid-esophagus	110–120^0, neutral flexion	Left ventricle, mitral valve, aortic valve, pericardium, left atrium	Parastemal long axis with and without color	LV function, catastrop mitral/aortic valve lesion, pericardial effusion
Transgastric short axis	Mid-stomach	0^0, anteflexed	Left ventricle	Parasternal short	LV function, pericardium effusion
Bicaval view with M-mode	Mid-esophagus	90–100^0, neutral flexion	Superior vena cava, inferior vena cava, right atrium	Subcostal IVC	Hypovolemia/volume reoonsiveness procedural guidance

Notes. LV = left ventricular. RV = right ventricular. IVC = inferior vena cava.

From Table 2 of Arntfield R, Pace J, McLeod S, Granton J, Hegazy A, Lingard L. Focused transesophageal echocardiography for emergency physicians-description and results from simulation training of a structured four-view examination. *Critical Ultrasound Journal*. 2015;7(1):27. doi:10.1186/s13089-015-0027-3.

cardiac arrest. A consensus statement by the ACEP for focused TEE in cardiac arrest recommends 2 to 4 hours of TEE specific education, minimum of 10 proctored TEE examinations (including probe insertion) on live patients and simulations models, and a completed standardized assessment by a TEE credentialed provider (ACEP 2017). The ACEP policy statement also recommends 3 views for cardiac arrest. The recommend 3 views by ACEP for a focused TEE exam are the mid-esophageal 4-chamber, mid-esophageal long axis view, and the transgastric short axis view.

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Keywords/Tags: Cardiac arrest, TEE, mid-esophageal 4-chamber, transgastric short axis, mid-esophageal long axis, transgastric long axis

Learning Point 41: A focused TEE involving four basic windows can be used in cardiac arrest to facilitate etiology as well as the location and adequacy of chest compressions.

42. EXPLANATION

A. Point-of-care TTE. A focused TTE exam has been shown to be feasible and effective in assessing hemodynamic status and cardiac function (Kanji 2014; Shokoohi 2017). The initial choice for POCUS should be to perform TTE for hemodynamic assessment. There is evidence that point-of-care TEE can be performed for hemodynamic assessment. However, the recommendations are to use TEE only when TTE has been initially attempted and is unable to adequate views or data (Arntfield 2018; Hahn 2013; Vignon 1994). TEE is considered significantly more invasive than TTE since it involves inserting a transducer into the patient's oral pharynx, esophagus, and stomach. The overall complication rate is approximately 1% to 2%. The most common complications of TEE are lip injury (13%), hoarseness (12%), and dysphagia (1.8%). Major complications are not as common but include esophageal perforation (0.3%), major bleeding (0.8%), and arrhythmia (0.3%). Table 2.2 lists absolute and relative contraindications for TEE. TEE offer advantages over TTE since TEE can obtain high-quality images due to the transducer's esophageal location, which is directly posterior to the heart. This allows for higher quality image acquisition and can help acquire data when TTE views are inadequate. TEE is superior to TEE when assessing for valvular pathologies such as endocarditis, valvular area estimation, aortic dissection, and thrombus evaluation (Hahn 2013). The advantage of TTE over TEE is that it is readily available, repeatable, noninvasive, and has

Table 2.2. **LIST OF ABSOLUTE AND RELATIVE CONTRAINDICATIONS TO TRANSESOPHAGEAL ECHOCARDIOGRAPHY**

ABSOLUTE CONTRAINDICATIONS	RELATIVE CONTRAINDICATIONS
• Perforated viscus	• History of radiation to neck and mediastinum
• Esophageal stricture	• History of GI surgery
• Esophageal tumor	• Recent upper GI bleed
• Esophageal perforation, laceration	• Barrett's esophagus
• Esophageal diverticulum	• History of dysphagia
• Active upper GI bleed	• Restriction of neck morbidity (severe cervical arthritis, atlantoaxial joint diseases)
	• Symptomatic hiatal hernia
	• Esophageal varices
	• Coagulopathy, thrombocytopenia
	• Active esophagitis
	• Active peptic ulcer diseases

Note. GI = gastrointestinal.

Adapted from Table 6 of: Hahn RT, Abraham T, Adams MS, et al. Guidelines for performing a comprehensive transesophageal echocardiographic examination: recommendations from the American Society of Echocardiography and the Society of Cardiovascular Anesthesiologists. *J Am Soc Echocardiogr.* 2013;26(9):921–964. doi:10.1016/j.echo.2013.07.009.

a negligible complication rate. Lactate level can be used to assess for degree of hypoperfusion but is nonspecific and can be seen in many causes of shock. In addition, at most institutions, lactate level can take 1 to 2 hours before resulting to the clinicians, whereas POCUS can be performed immediately; thus, answer C is incorrect. End-tidal CO_2 monitoring can be used to assess adequacy of chest compression and return of spontaneous circulation in cardiac arrest patients. However, it has minimal value in determining the direct causes of shock; thus, answer D is incorrect.

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Keywords/Tags: Cardiac arrest, TTE, TEE, transesophageal echocardiography, TTE, advantages, disadvantages

Learning Point 42: TTE and TEE can both be used in cardiac arrest scenarios to rapidly characterize the etiology of shock, as well as to guide ACLS.

43. EXPLANATION

C. Obstruction from sarcoma. The media in this question shows a large RA mass causing obstructive symptoms. In addition, there is a pericardial effusion seen on the ultrasound. Cardiac tumors occur in 0.1% of the population. The presenting symptoms are usually nonspecific and can resemble heart failure symptoms. Tumors arising from the atria or atrioventricular valves can mimic mitral stenosis, tricuspid stenosis, and superior vena cava syndrome. Diagnosis is often incidental when the patient is being worked up for new symptoms of heart failure. The majority of adult cardiac tumors are benign (85%), and the most common is myxomas. Myxoma on ultrasound appears as a heterogenous mobile mass and can arise in either the right or left atrium, but 80% of the time they are in the left atrium. Malignant tumors are the cause of approximately 15% of primary cardiac tumors. However, if a tumor presents on the right side of the heart, there is a 50% chance of the tumor being malignant, as in our case. Additional signs of malignant cardiac tumor are rapid growth, local invasion, and pericardial effusion.

Sarcomas are the most common causes of malignant cardiac tumors with average age of diagnosis in the mid-40s. The most common type of sarcoma is angiosarcoma, and the second most common is rhabdomyosarcoma. Angiosarcoma tumors almost always arise from the right atrium and often have direct involvement with the pericardium resulting in pericardial effusion. The patient in this case has findings most indicative of an angiosarcoma given the mass is arising from the right atrium with associated pericardial effusion. The mass was urgently resected with confirmation of angiosarcoma from pathology.

Other common malignant cardiac masses that metastasize from other sites include lymphoma and carcinoid syndrome. Answer A is incorrect; left-sided heart failure is unlikely to be the source of symptoms in this patient since there is no evidence of pulmonary edema, and there is a clear alternative source for his lower extremity edema. Answer B is incorrect; myxoma could be the cause however the majority of myxomas arise in the left atrium and pericardial effusion is not associated with benign cardiac tumors. Answer D is incorrect; intracardiac thrombi usually are found in low-flow cardiac output states and are not highly mobile. The mass in the case is very highly mobile and well circumscribed, suggesting thrombus is unlikely.

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Keywords/Tags: Cardiac mass, sarcoma, myxoma

Learning Point 43: Malignant cardiac masses include intrinsic masses such as angiosarcomas, rhabdomyosarcomas, and leiomyosarcomas. Common malignant cardiac masses that metastasize from other sites include lymphoma and carcinoid syndrome.

3.

PHYSICS AND KNOBOLOGY

Claire Abramoff, John Lemos, Usama Khalid, and Sierra Beck

QUESTIONS

1. A pregnant female patient asks you if she should buy a popular home ultrasound machine to monitor her fetus. You would not recommend this because of:

A. Principle of ALARA
B. Ramzi Theory
C. Nub Theory
D. Proven harm to fetus

2. You are considering doing a thorough lung ultrasound on a dyspneic patient to look for the presence of B-lines, sliding, and pleural effusions. However, you have been reading current literature that suggests that lung ultrasound in rats can cause areas of pulmonary hemorrhage. You see several values displayed on the ultrasound screen. Which value best represents the amount of energy transmitted into tissue during lung ultrasound?

A. MI
B. Frequency (29 Hz)
C. Gain (Gn 56)
D. Depth (18 cm)

3. You have a young male patient who you are concerned has testicular torsion. You are considering doing a bedside testicular ultrasound to help you in your decision to consult urology. However, you remember learning that significant temperature elevations can cause damage to sperm and can have a negative impact on fertility. What mode of ultrasound poses the greatest risk of these thermal bioeffects?

A. B-mode
B. M-mode
C. Spectral Doppler
D. Color Doppler

4. What are the two artifacts seen in the images of the gallbladder shown in Figure 3.1?

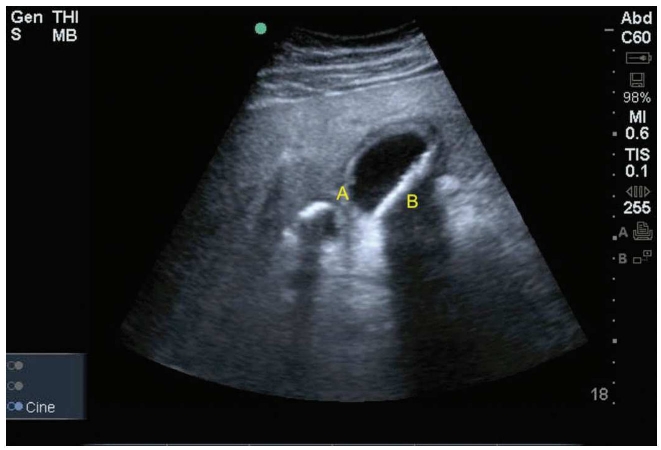

Figure 3.1

A. Side-lobe and ring-down artifacts
B. Side-lobe and reverberation artifacts
C. Edge and shadowing artifacts
D. Edge and mirror image artifacts

5. You are performing the suprapubic views of a focused assessment with sonography in trauma (FAST) exam and obtain the transverse view of the bladder seen in Figure 3.2.

Figure 3.2

How can your far field image quality be improved?

A. Increase the field depth
B. Decrease the field depth
C. Select a different probe
D. Turn down the gain/time-gain compensation (TGC)

6. What type of artifact is seen in Figure 3.3?

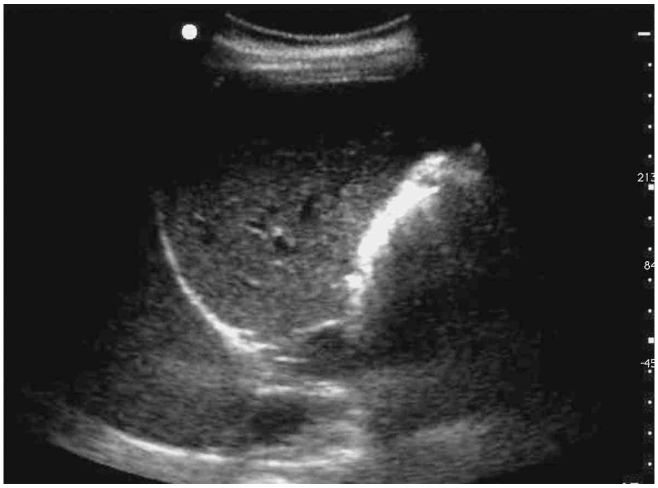

Figure 3.3

A. Ring down artifact
B. Reverberation artifact
C. Mirror artifact
D. Side-lobe artifact

7. Which of the following is true of beam-width artifact?

A. It can be adjusted by increasing near field gain.
B. It is a property inherent to the shape of the emitted ultrasound beam.
C. It occurs when a reflective object is encountered by the ultrasound beam before the focal zone.
D. It is typically found around echoic structures.

8. You are imaging a hydrocele and note some abnormal echoes within the anechoic fluid. What is the name of the artifact seen at the asterisk in Figure 3.4?

A. Twinkle artifact
B. Side-lobe artifact
C. Reverberation artifact
D. Ring-down artifact

9. Identify the artifact seen in Figure 3.5:

A. Twinkle artifact
B. Side-lobe artifact
C. Reverberation artifact
D. Edge artifact

Figure 3.4

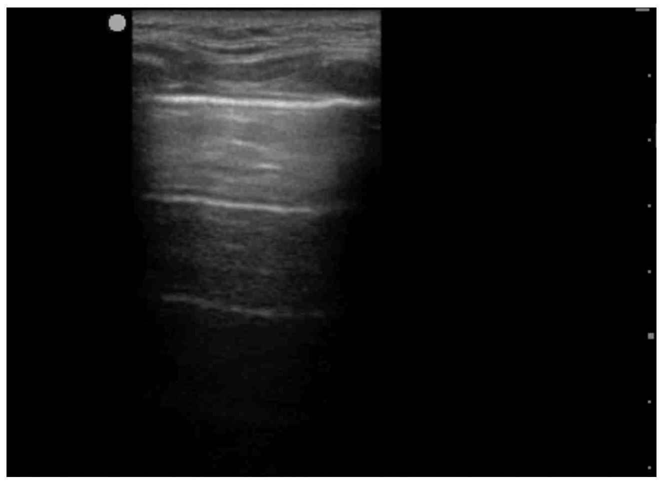

Figure 3.5

10. A 26-year-old man presents with sharp right flank pain and nausea for the past day. He denies dysuria and hematuria. His vital signs are significant for tachycardia to 112. He appears in moderate distress but is not altered. He has right costovertebral angle (CVA) tenderness, but his abdomen is benign. While waiting for his serum and urine studies, you perform the ultrasound shown in Figure 3.6 with and without color Doppler.

What is the artifact that you see on color Doppler?

A. Twinkle artifact
B. Side-lobe artifact
C. Reverberation artifact
D. Ring-down artifact

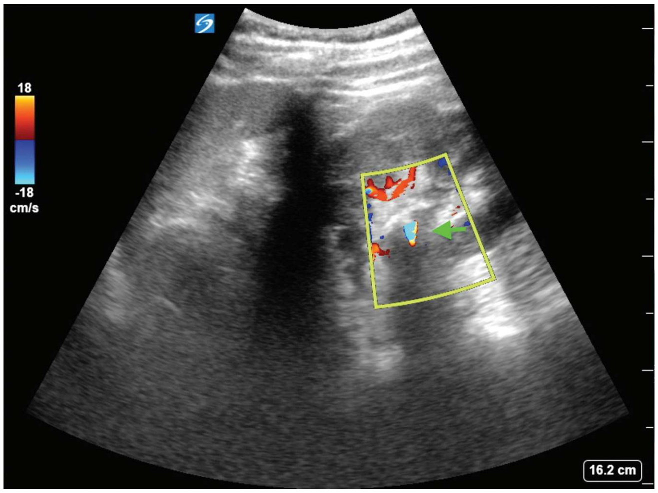

Figure 3.6

11. What artifact is shown in the pulsed wave Doppler (PWD) image in Figure 3.7?

A. Twinkle artifact
B. Aliasing artifact
C. Reverberation artifact
D. Ring-down artifact

12. When imaging the soft tissues, structures may become more or less echogenic depending on the angle of ultrasound beam. This artifact is known as:

A. Twinkle artifact
B. Aliasing artifact
C. Anisotropy
D. Ring-down artifact

13. Which of the following modes of ultrasound utilizes an unlimited transmit time, essentially equating to a Duty Factor of 1?

A. Figure 3.8a (M-mode)
B. Figure 3.8b (CWD)
C. Figure 3.8c (pulse wave Doppler)
D. Figure 3.8d (color Doppler)

14. While performing a transabdominal pelvic ultrasound on a patient in her first trimester, you identify a fetal pole with cardiac activity and would like to measure the heart rate. With the ALARA principle in mind, which of the following modes should you use?

A. B-mode
B. Color Doppler
C. M-mode
D. Power Doppler

15. You are demonstrating the use of power Doppler in the assessment of testicular flow. A student asks: "What does signal intensity represent?" Which of the following is an accurate response?

A. The velocity and direction of flow
B. Velocity of flow independent of direction
C. The number of moving particles, not velocity
D. Pulsatility of flow

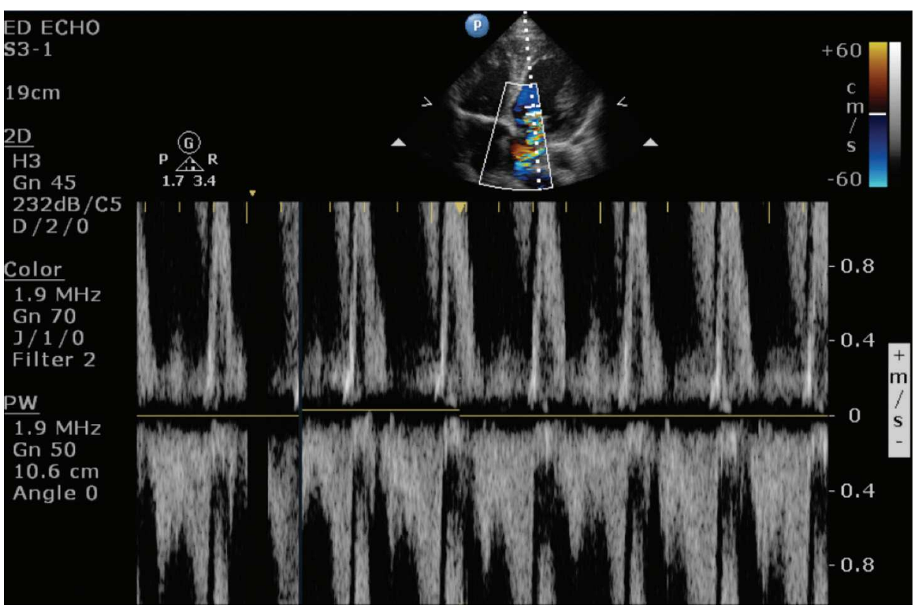

Figure 3.7

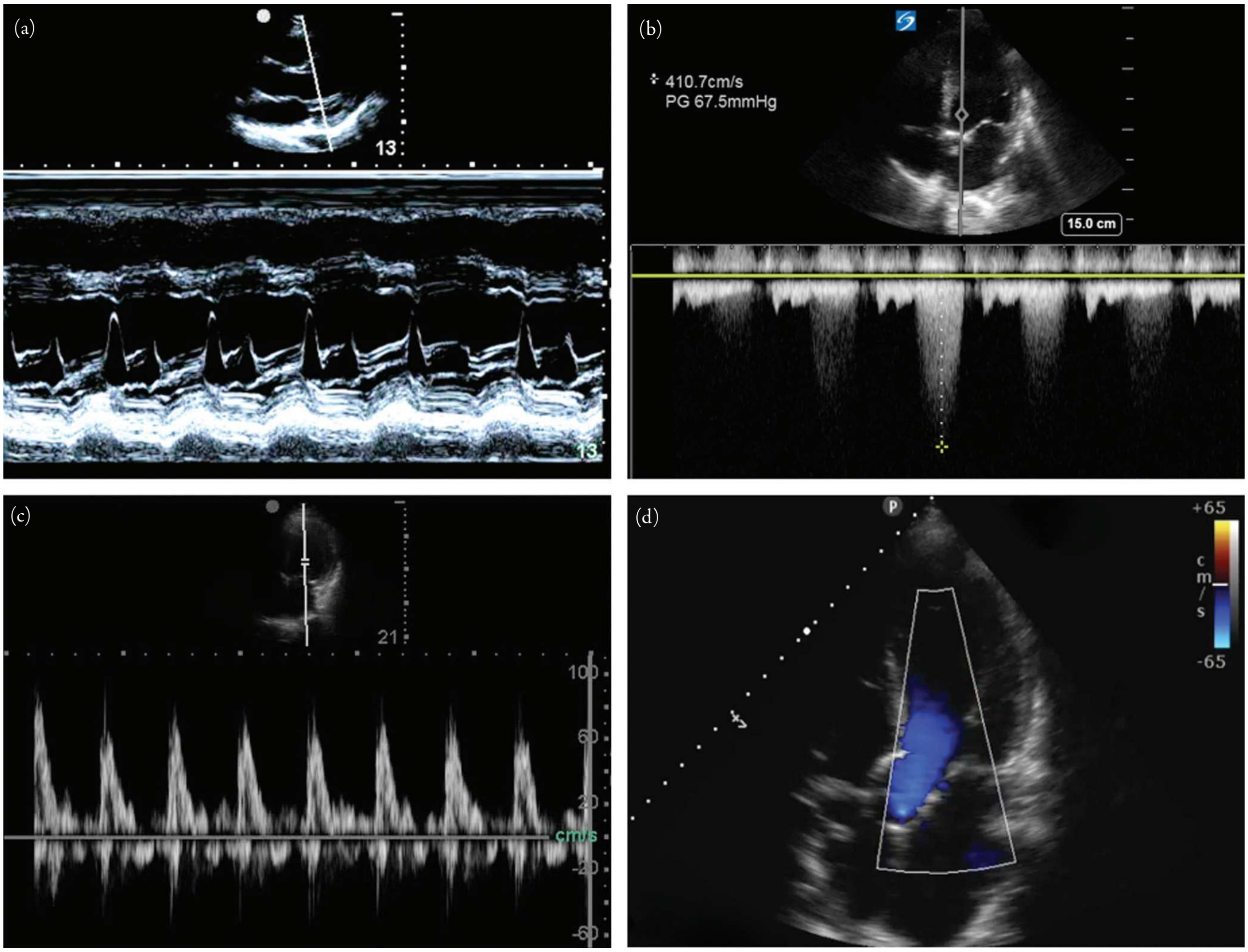

Figure 3.8

16. A patient is undergoing echocardiographic assessment due to a clinical concern for new onset heart failure. In the assessment of diastolic dysfunction, which of the following is the most appropriate mode to assess mitral inflow velocity?

A. Continuous wave Doppler
B. Color Doppler
C. Pulsed wave Doppler
D. Power Doppler

17. You perform a RUQ ultrasound on a patient with right-sided abdominal pain. Which image in Figure 3.9 is correctly oriented and why?

A. Left image because the indicator should point caudal
B. Left image because the indicator should point cephalad
C. Right image because the indicator should point cephalad
D. Right image because the indicator should point caudal

18. Which cardinal movement of the ultrasound probe would be the quickest way to check for free fluid above the right hemidiaphragm after assessing Morrison's pouch?

A. Fanning
B. Sliding
C. Compression
D. Rotation

19. In Figure 3.10, an image of a pleural effusion, the rib is _____ compared to the ______ effusion.

A. Hypoechoic, isoechoic
B. Anechoic, hyperechoic
C. Hypoechoic, hyperechoic
D. Hyperechoic, anechoic

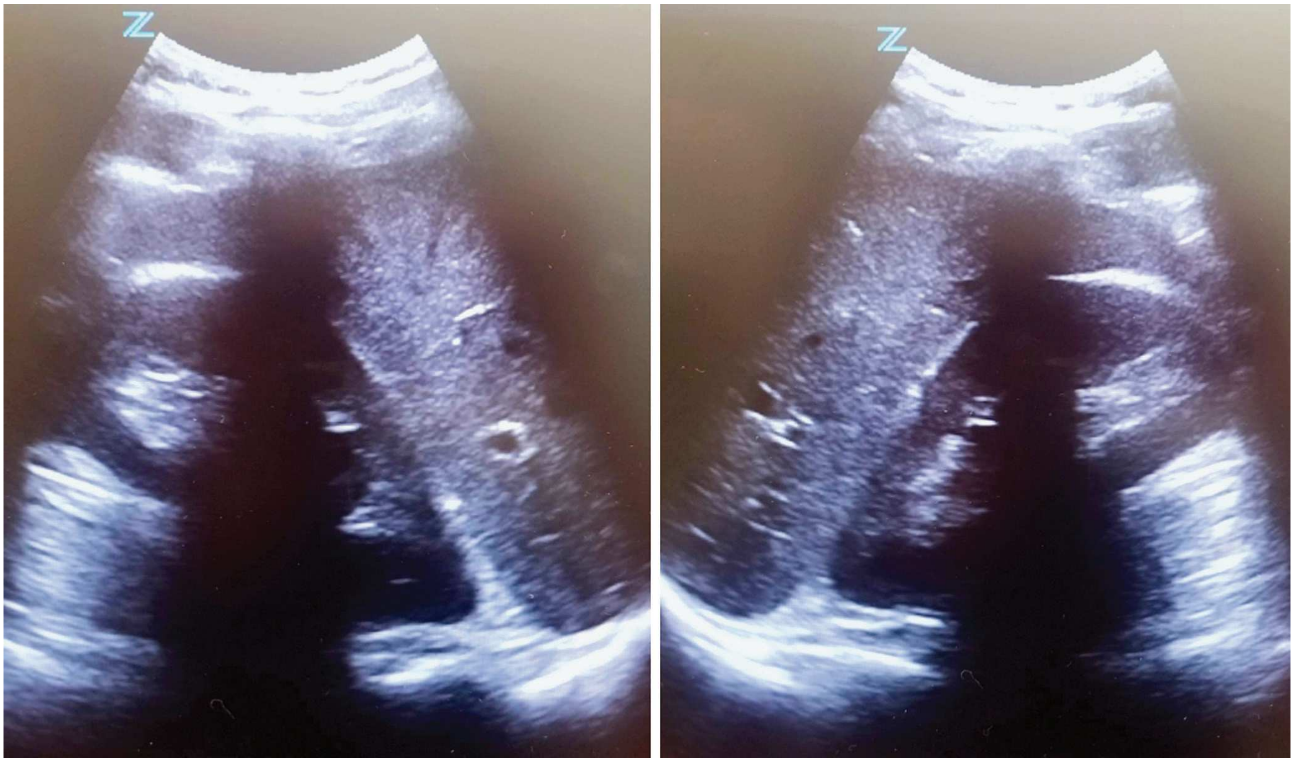

Figure 3.9

20. You are trying to improve the quality of the ultrasound image in Figure 3.11. What is one easy way to improve your image quality?

A. Increase the depth
B. Decrease the far-field gain
C. Switch to the high-frequency linear array probe
D. Change the preset to “abdominal”

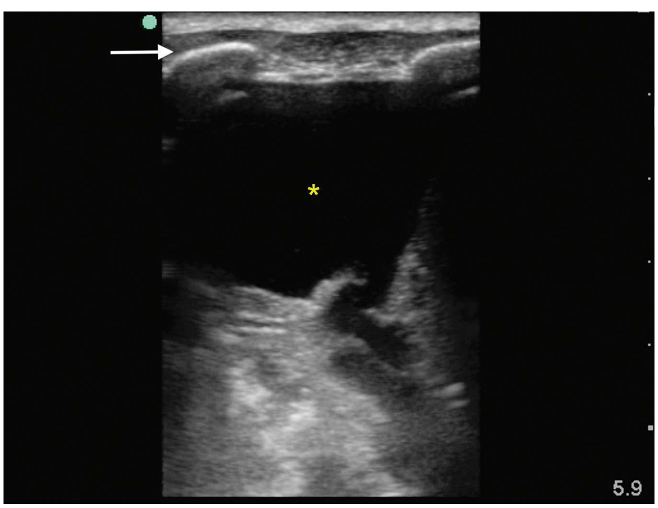

Figure 3.10

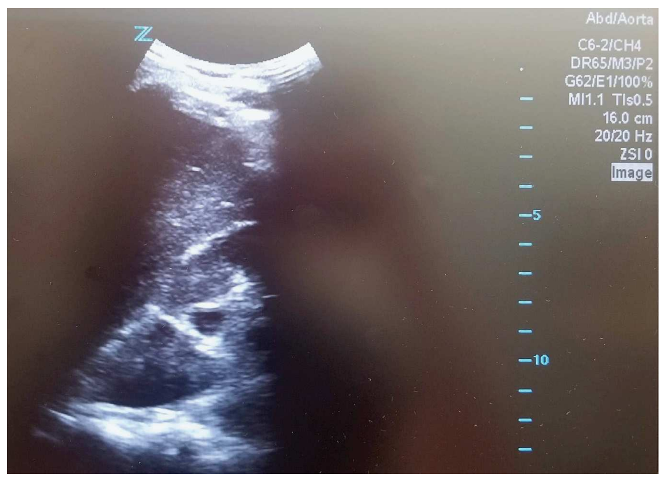

Figure 3.11

21. You are attempting to obtain central access on a hypotensive septic patient to start pressors. Which ultrasound probe should you use when placing an ultrasound-guided central line in the internal jugular vein?

A. Phased array
B. Curvilinear
C. Linear
D. Endocavitary

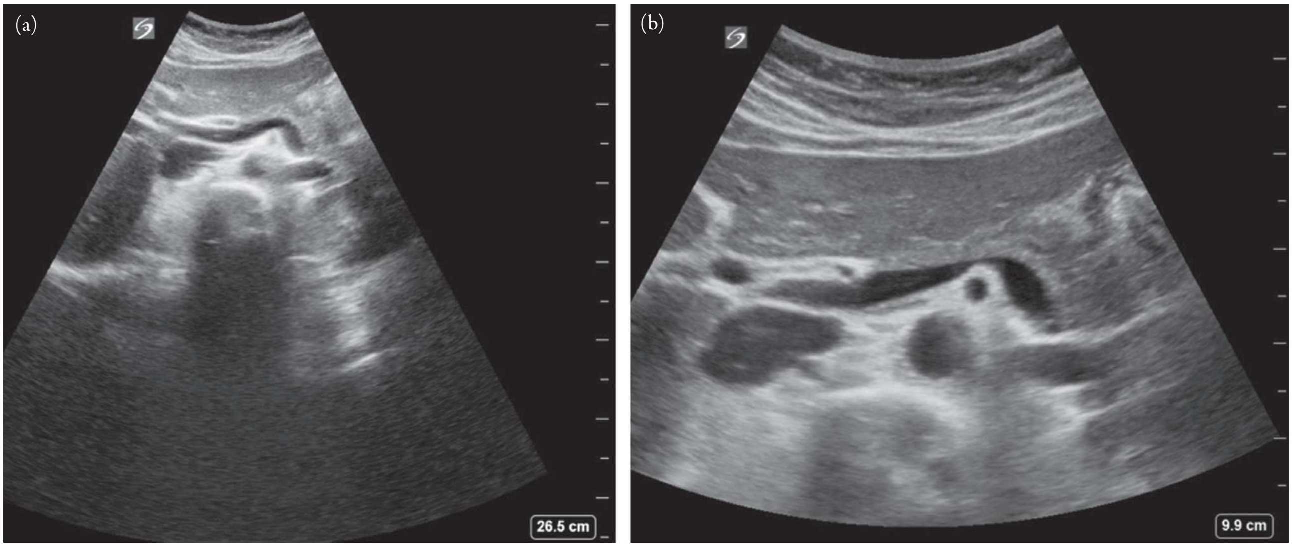

Figure 3.12

22. What is a simple way to improve the resolution of the image in Figure 3.12a so that it looks like the image in Figure 3.12b?

A. Decrease depth
B. Increase gain
C. Switch to the linear probe
D. Switch to the phased array probe

23. What is a simple way to improve the quality of the image in Figure 3.13a so that it looks like the image in Figure 3.13b?

A. Increase the depth
B. Switch to the linear probe
C. Decrease the gain
D. Switch to the phased array probe

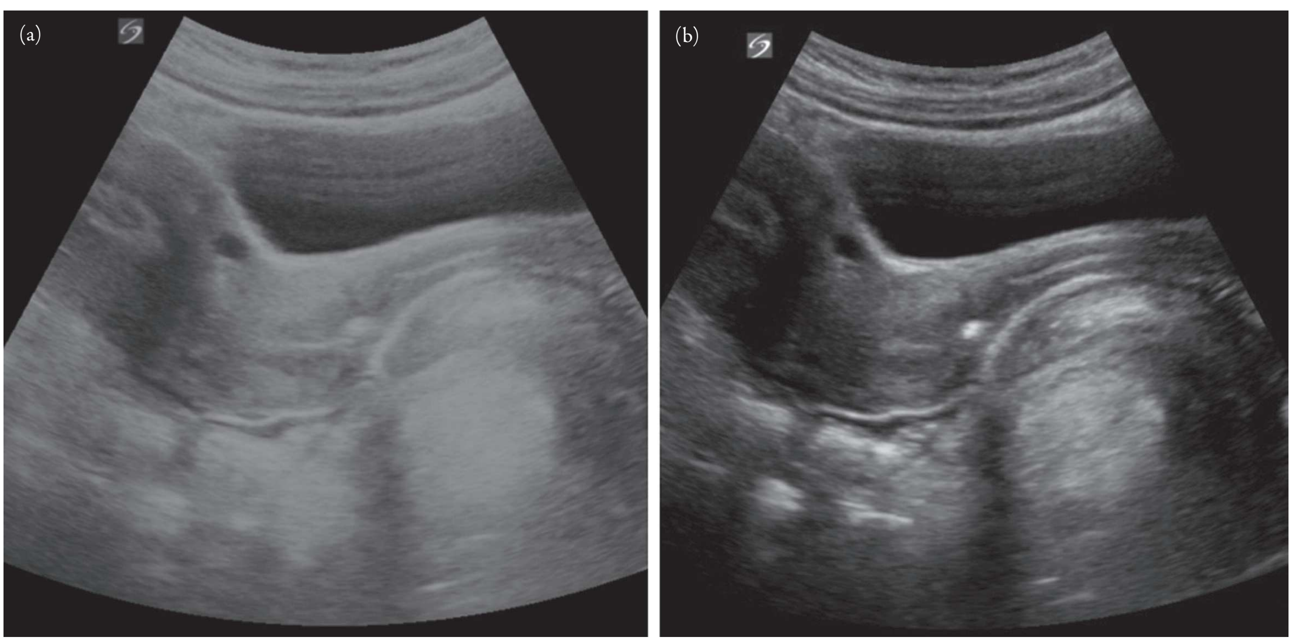

Figure 3.13

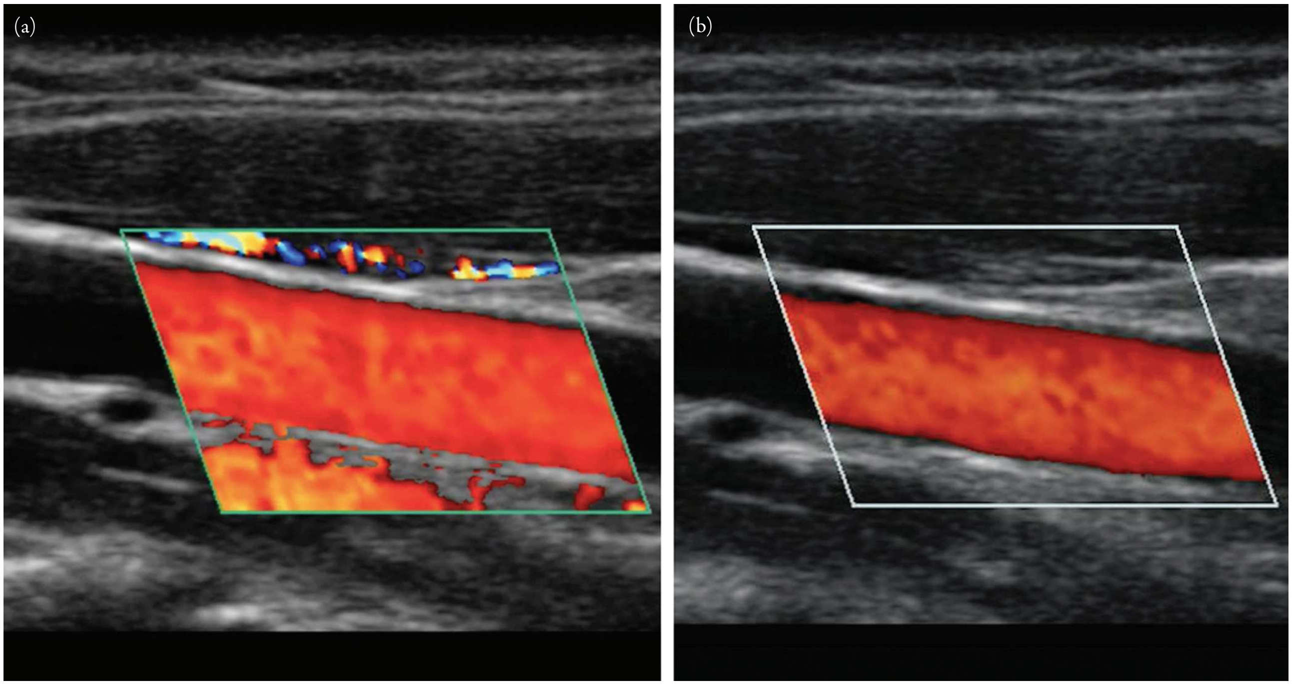

Figure 3.14

24. You are attempting to evaluate for flow in the carotid artery. What can you do to optimize the image in Figure 3.14a so that it looks like the image in Figure 3.14b?

A. Decrease the color gain
B. Decrease the scale
C. Decrease the wall filter
D. Switch to a lower frequency probe

25. What does the blue area of the image in Figure 3.15 represent?

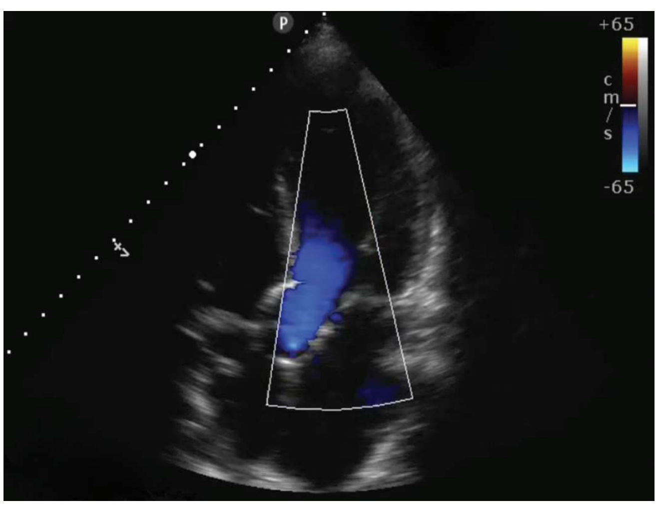

Figure 3.15

A. Normal blood flow toward the probe
B. Aortic regurgitation directed toward the probe
C. Aortic stenosis directed away from the probe
D. Normal blood flow away from the probe

26. You are evaluating a patient for possible mitral regurgitation from endocarditis. Which of the following adjustments may improve aliasing seen in the image in Figure 3.16?

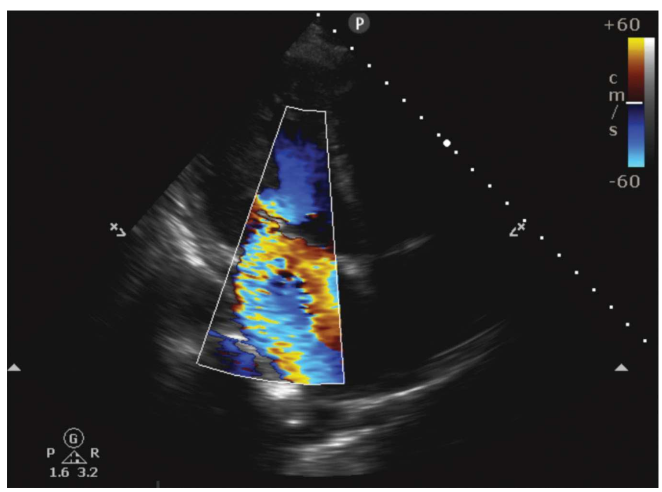

Figure 3.16

A. Increase the scale
B. Choose a different window to increase the depth of sampling area
C. Use a higher frequency transducer
D. Switch to PWD mode

27. You are performing an ultrasound to evaluate a patient prior to incision and drainage of a presumed abscess and you visualize a hypoechoic area on B-mode imaging. You are uncertain if this is a lymph node or abscess. You place a color flow box over the area and obtain the image shown in Figure 3.17.

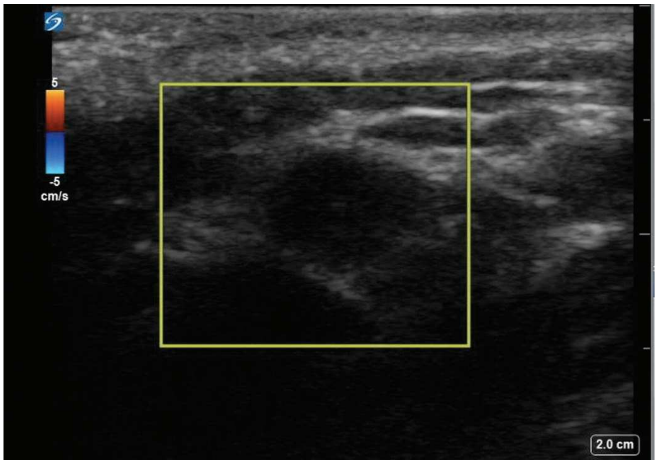

Figure 3.17

Which of the follow adjustments may help you to visualize low velocity flow that may have been missed?

A. Switch to CPD
B. Increase the scale
C. Decrease the gain
D. No adjustments needed: settings are appropriate, no flow is present, and it is safe to proceed with procedure

28 You are performing a carotid ultrasound and note the appearance of flow outside of the vessel. You have optimized the color gain. Which additional adjustment may remove the artifact seen in Figure 3.18?

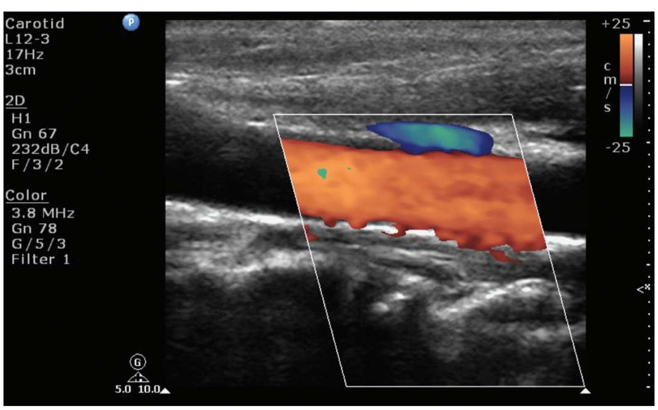

Figure 3.18

A. Decreasing the wall filter
B. Increasing the wall filter
C. Increasing the steering angle
D. Decreasing the steering angle

29. You are attempting to place a radial artery catheter using ultrasound guidance. You place the probe on the wrist exactly perpendicular to the vessel and turn on color mode. You see pulsation on your 2D B-mode image but are unable to see flow in color mode (Figure 3.19a). Why is this?

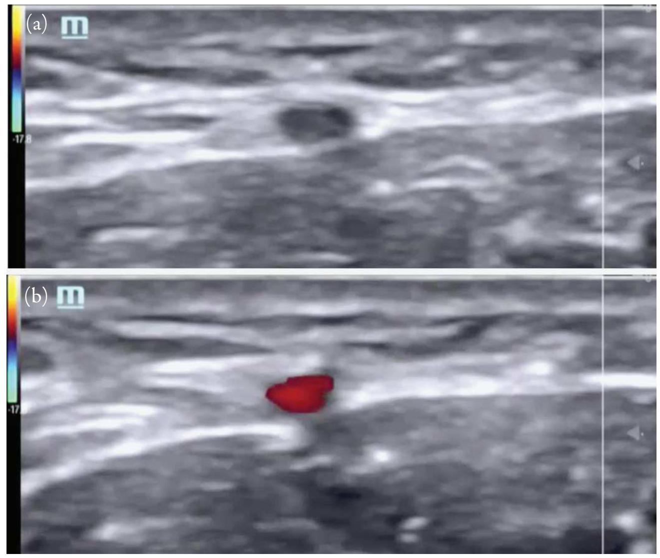

Figure 3.19

A. Angle dependence of Doppler ultrasound
B. You are approaching the Nyquist limit
C. You are imaging a vein
D. Flash artifact

30. You are unable to locate an audible Doppler and want to evaluate arterial blood flow using PWD. Which of the following images demonstrates correct PWD gate positioning, gate size, and steering to most accurately measure blood flow velocity?

A. Figure 3.20a
B. Figure 3.20b
C. Figure 3.20c
D. Figure 3.20d

31. Which of the following would represent normal peak blood velocities at rest within the following anatomic structures?

A. Left ventricular outflow tract during systole 400 m/s, carotid artery 40 m/s, testicular arteriole 4 m/s, inferior vena cava (IVC) 0.4 m/s.
B. Left ventricular outflow tract during systole 40 cm/s, carotid artery 50 cm/s, testicular arteriole 4 cm/s, IVC 0.4 cm/s.

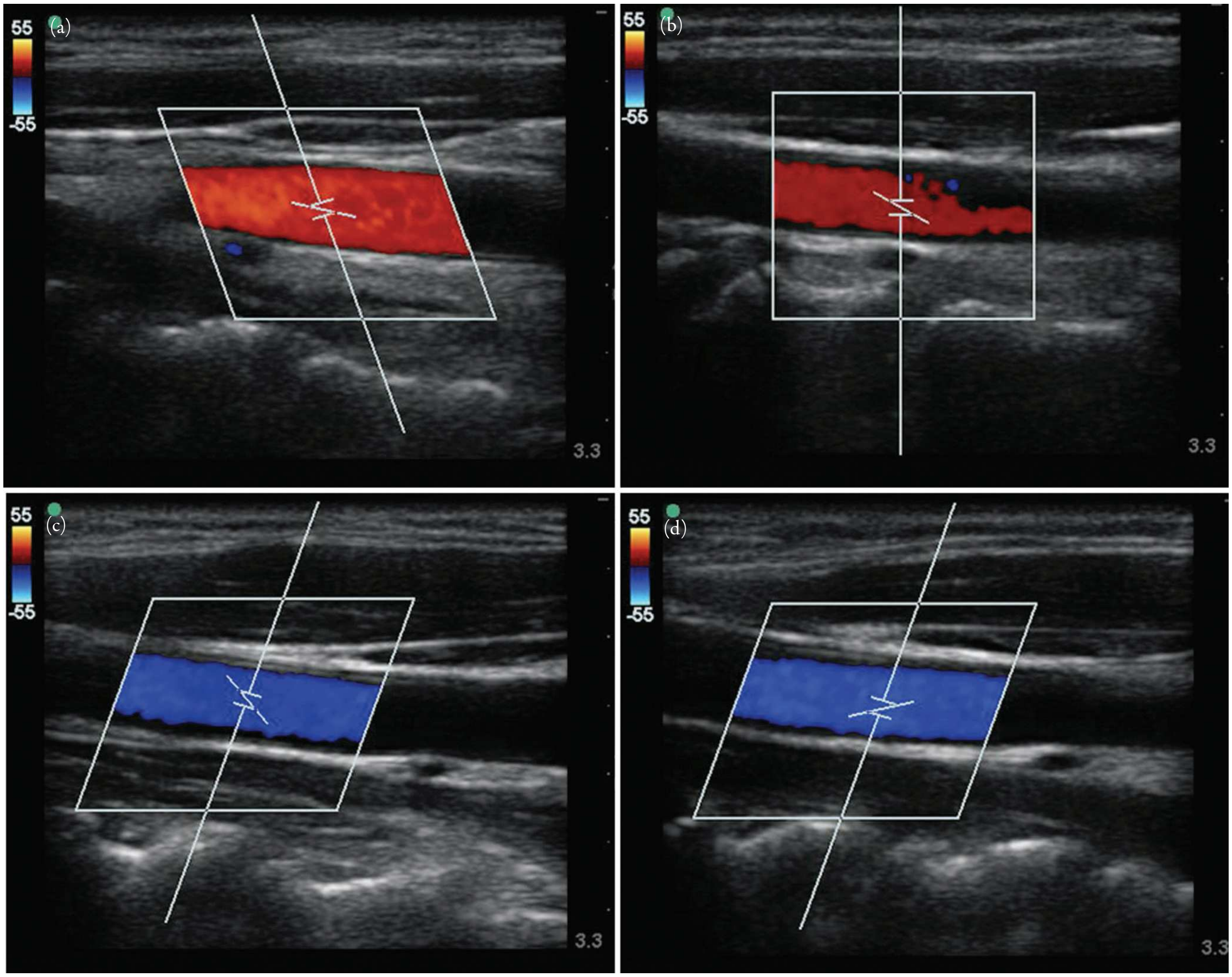

Figure 3.20

C. Left ventricular outflow tract during systole 400 cm/s, carotid artery 40 cm/s, testicular arteriole 0.4 cm/s, IVC 0.4 cm/s.
D. Left ventricular outflow tract during systole 400 m/s, carotid artery 40 m/s, testicular arteriole 4 m/s, IVC 0.4 m/s.

32. You are attempting to calculate the right ventricular systolic pressure (RVSP) and have obtained the tracing of a tricuspid regurgitant jet shown in Figure 3.21. How can you correct this image?

A. Switch modes to CWD
B. Decrease the scale and increase the wall filter
C. Increase the gain and increase the wall filter
D. Move baseline downward

33. To optimize image quality and increase the frame rate when using color Doppler, the color box should be adjusted to be:

A. Small and superficial
B. Larger and superficial
C. Small and deep
D. Large and deep

34. While performing an ultrasound of a patient's lower extremity. The sonographer switches from a low frequency (3 MHz) to a high frequency (10 MHz) source to improve image resolution. Which of the following acoustic parameters will remain unchanged and/or constant as it travels through a specific soft tissue medium?

A. Wavelength
B. Period
C. Propagation speed
D. Intensity

35. You are evaluating the appendix of an 8-year-old patient with a high-frequency linear transducer. The patient has an obese habitus, resulting in deeper intraperitoneal structures as well as a poor image resolution. Your instructor attributes this to image attenuation and asks you to make an adjustment to your approach.

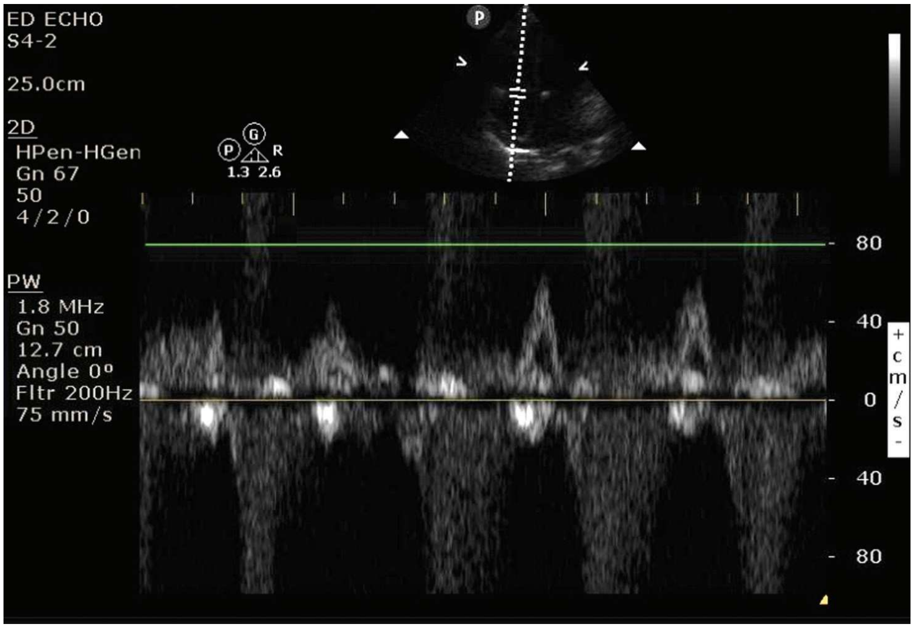

Figure 3.21

Which of the following is most likely to be helpful in image acquisition?

A. Increase the frequency as attenuation is inversely proportional to frequency.
B. Increase the gain as attenuation is inversely proportional to gain.
C. Decrease the gain as attenuation is inversely proportional to gain.
D. Decrease the frequency as attenuation is directly proportional to frequency.

36. While demonstrating ultrasonographic assessment of the gallbladder, a rib shadow causes obstruction of your view. One of your students inquires why bone causes shadowing when, according to her recent reading, the speed of propagation of sound is greater in bone as compared to soft tissue. Which of the following is the most accurate response?

A. Bone has a much lower attenuation coefficient.
B. Bone has a much higher attenuation coefficient.
C. Bone absorbs less sound than soft tissue.
D. Bone reflects all of the sound waves, resulting in shadowing.

37. While demonstrating normal lung ultrasound, you explain to your students that A-lines occur due to a reciprocal reflection of sound between the pleural surface and skin. One of them asks why this artifact is not present with consolidated lung. Which of the following is the most accurate response?

A. Air does not transmit sound waves and reflects them all.
B. Consolidated lung has a higher velocity of propagation than the pleural surface.
C. The relative impedance mismatch is greater in aerated lung, resulting in increased reflection.
D. The relative impedance mismatch is greater in consolidated lung, resulting in decreased reflection.

ANSWERS

1. EXPLANATION

A. Principle of ALARA. As with all things in medicine, the benefit of ultrasound (in terms of diagnosis or treatment) must outweigh the risks of the procedure. Ultrasound exposure must be kept ALARA due to theoretical risks of tissue heating. Currently, the American College of Obstetrics and Gynecology recommends that obstetric ultrasounds only be performed for medical purposes by a qualified healthcare provider. Thus, home ultrasonography to monitor the fetus would violate ALARA and has the potential to cause harm to the developing fetus. Ramzi Theory and Nub Theory are methods to predict the gender of the fetus using ultrasound during the first trimester. The risks of tissue heating by ultrasound are theoretical and there has not been any documented in vitro harm caused by ultrasound, so answer D is not correct.

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Keywords/Tags: OB, ALARA

Learning Point 1: Ultrasound exposure must be kept *as low as reasonably achievable (ALARA)* due to theoretical risks of tissue damage.

2. EXPLANATION

A. MI. The MI is a way to estimate the amount of energy being transmitted into a tissue during ultrasound. The theory behind the MI is that sound waves can cause oscillation and collapse of gas-filled bubbles in tissues, which leads to physical damage such as cavitation. Gas-filled tissues (lung, bowel) are thought to be at higher risk to this type of damage. The FDA mandates that all machines calculate and display the MI, and it is recommended that the MI remains <1.9. MI is determined by the following formula:

$$\text{Peak Negative Pressure}\left(\text{PNP}\right)\sqrt{\text{Center Frequency}}$$

Thus, answers B and C are incorrect. The frequency, not depth, of the ultrasound waves is also related to the MI—higher frequency ultrasound waves have a lower MI than lower frequency waves.

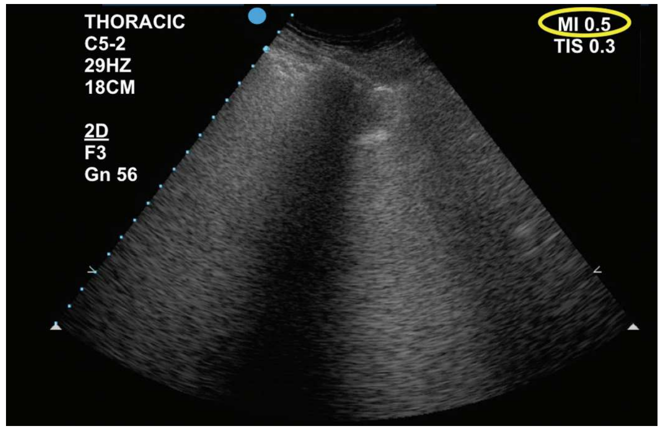

Figure 3.22 **Ultrasound screen with mechanical index.**

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Edelman SK. In: Edelman SK. *Understanding Ultrasound Physics*. 4th ed., Chapter 19, Doppler. Woodlands, TX: ESP; 2012:380.

Miller DL, Suresh MV, Dou C, Yu B, Raghavendran K. Characterization of ultrasound-induced pulmonary capillary hemorrhage in rats. *Microvasc Res*. 2014;93:42–45. doi:10.1016/j.mvr.2014.02.006.

Keywords/Tags: Mechanical index, pulmonary ultrasound

Learning Point 2: The mechanical index (MI) is a way to estimate the amount of energy being transmitted into a tissue during ultrasound, with a MI ≤1.9 considered generally safe.

3. EXPLANATION

C. Spectral Doppler. The temperature increase during exposure to diagnostic ultrasound is dependent on properties of the acoustic source and tissue properties. Ultrasound modes that increase the acoustic power have higher thermal indices. In general, temperature elevations become progressively greater from B-mode and M-mode to color Doppler to spectral Doppler modes. The thermal index (TI) is an estimate of the maximal temperature increase that occurs during ultrasonography. This may be displayed on the ultrasound screen as the soft tissue thermal index (TIS) or the bone thermal index (TIB). The TI roughly estimates the maximal increase in temperature that tissues experience under most clinical conditions. For example, if the TI is 1, the maximal expected increase in temperature is approximately 1°C. Longer scanning times increase the risk of thermal damage. Thus, as TI increases, recommended scanning time decreases.

Fetal tissue, eyes, testes, and brain tissue are thought to be at highest risk of thermal damage. General consensus is that

Table 3.1. **THERMAL INDEX AND MAXIMUM SCANNING TIMES**

TI RANGE	MAXIMUM SCANNING TIME	
	Adult transcranial, general abdominal, peripheral vascular, neonatal (except head and spine), and other scanning examinations (except eye)	Obstetric, neonatal transcranial, and spinal
> 6.0	Not recommended	Not recommended
5.0–6.0	Less than 15 seconds	Not recommended
4.0–5.0	Less than 1 minute	Not recommended
3.0–4.0	Less than 4 minutes	Not recommended
2.5–3.0	Less than 15 minutes	Less than 1 minute
2.0–2.5	Less than 60 minutes	Less than 4 minutes
1.5–2.0	Less than 120 minutes	Less than 15 minutes
1.0–1.5	No time limit	Less than 30 minutes
0.7–1.0	No time limit	Less than 60 minutes
<0.7	No time limit	No time limit

Note. TI = thermal index. Note that there are no ocular, ovarian, or testicular recommendations. In general, these tissues are equally or more likely sensitive to heat as the tissues listed on the right column. Adapted from Harris GR, Church CC, Dalecki D, Ziskin MC, Bagley JE. Comparison of thermal safety practice guidelines for diagnostic ultrasound exposures. *Ultrasound Med Biol.* 2016;42:345–357.

a temperature increase of ≤1.5°C is safe, whereas an increase in fetal tissue of ≥4°C for more than five minutes is dangerous. Table 3.1 shows maximum scanning time recommendations for various tissues. Remember the principle of ALARA should always be applied and scanning time should be as short as possible to achieve necessary diagnostic information.

REFERENCES

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AIUM Official Statement. Statement on mammalian biological effects of heat. http://www.aium.org/officialStatements/17

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Keywords/Tags: Thermal index, testicular ultrasound, ALARA

Learning Point 3: The thermal index (TI) roughly estimates the maximal increase in temperature that tissues experience under most clinical conditions due to ultrasound.

4. EXPLANATION

C. Edge and shadowing artifacts. Figure 3.1 is a short axis view of the gallbladder. The thin anechoic vertical stripe just deep to A is consistent with edge artifact. The anechoic band below B is shadowing or attenuation artifact due to multiple gallstones. Note that there is also air artifact just to the left of the edge artifact, likely due to adjacent duodenum.

As seen in Figure 3.23, edge artifact (Panels A and C) occurs when a sound wave is refracted at a curved fluid-filled structure and does not return back to the transducer. Thus, the missing information from the area distal to the edge of the curved surface is registered as an anechoic stripe. It is important to not mistake this artifact as gallstone shadowing. Edge artifact may occur when imaging the eye, large vessels, fluid filled cysts, or the bladder. Shadowing artifact (Panels B and D) is also seen in this image. Shadowing occurs when the sound beam is attenuated by a strong reflector (the stone) and the entire sound beam is reflected back to the transducer. The resulting view on the ultrasound is a black shadow distal to the attenuating structure. Classic examples of shadowing include ribs and gallstones.

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Kelley K, Rose JS, Bair AE. Fundamentals of ultrasound. In: Cosby KS, Kendall JL. *Practical Guide to Emergency Ultrasound*. 2nd ed. Philadelphia, PA: Lippincott, Williams & Wilkins; 2014:10-19.

Keywords/Tags: Edge artifact, shadowing artifact

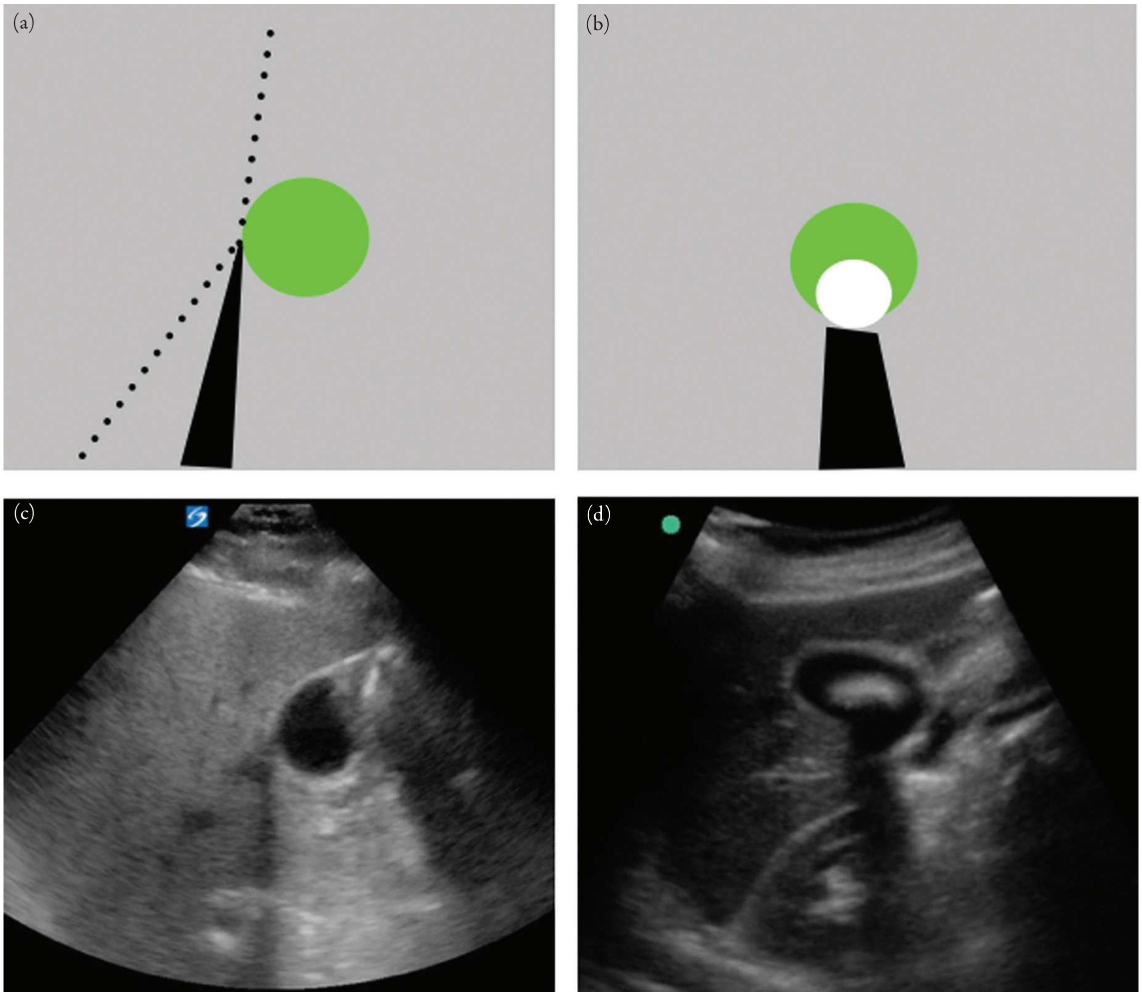

Figure 3.23 **Explanation of edge and shadowing artifact.**

Learning Point 4: Edge artifact is due to refraction of sound waves on a curved fluid-filled structure. Shadowing artifact is due to reflection and attenuation of a sound wave on a dense structure like stone or bone.

5. EXPLANATION

D. Turn down the gain/time-gain compensation (TGC). The images shown in the question illustrate a common artifact in ultrasound interpretation—posterior acoustic enhancement (PAE). Here, PAE is the bright white artifact distal to the bladder. PAE is commonly visualized off of the back wall of a fluid-filled structure and is caused by sound traveling at higher speeds through these structures. Simple cysts, eyes, and full bladders are common structures that display PAE. Gain refers to the degree of amplification of the returning sound or echo.

As seen in Figure 3.24, increasing or decreasing the gain will change the signal amplification for the entire image and create a "whiter" or more hyperechoic image (turn up gain) or a darker or more hypoechoic image (turn down gain). TGC adjusts gain at specific depths. This may be seen on your ultrasound machine as separate near field, far field, and overall gain adjustment knobs or with a series of sliding knobs that adjust gain at set depths.

REFERENCES

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Kressel HY, McLean GK, Troupin RH. Correlative Imaging Conference. *AJR*, 1980;(135):1305–1309.

Keywords/Tags: Posterior acoustic enhancement, PAE, artifact, gain, TGC

Learning Point 5: Decreasing far gain will mitigate posterior acoustic enhancement (PAE) in fluid-filled structures and improve image quality and interpretation.

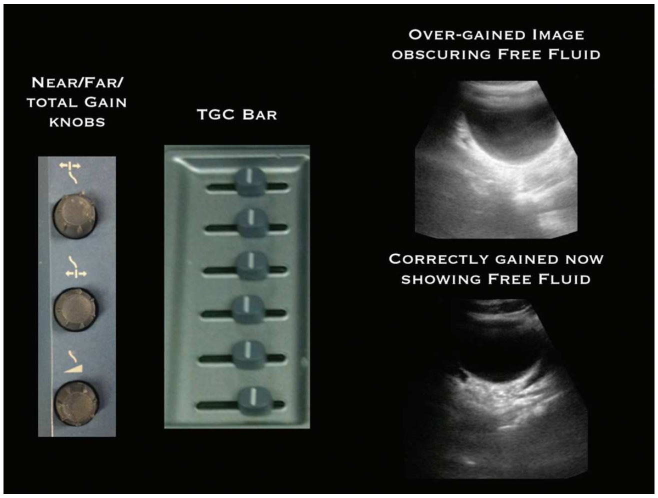

Figure 3.24 **Reducing far gain to minimize posterior acoustic enhancement.** Traditionally, mobile cart-based machines feature 3 knobs of gain adjustment. The top knob adjusts the gain for the top half of the screen; the middle knob adjusts gain for the bottom half of the screen; and the bottom knob adjusts gain for the entire screen. There is also an "auto gain" button (not shown) that adjusts gain to default levels. Time-gain compensation bars serve similar functions on traditionally larger and more sophisticated suite-based machines. The distinction between time-gain compensation bars and gain knobs continues to blur with touchscreen displays and handheld ultrasound systems.

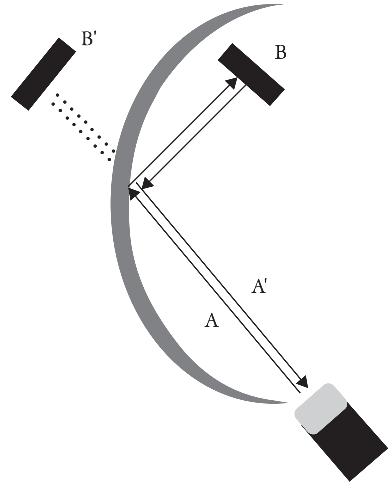

Figure 3.25 **Explanation of mirror image artifact.** The sound wave travels in path A and hits the bright reflector. It's echo (A') returns to the transducer and is translated as the image of structures along the path of A. However, some sound waves will bounce off the reflector surface, and travel in the path of B. The echo from path B will return along the original path, hit the reflector surface again, and travel in a similar fashion to A. However, it will be translated as structures along path B (or B') that is seen past the reflector surface, often in a mirror-image orientation. The classic mirror image artifact uses the diaphragm as the reflector surface and one or more vessels in the liver—such as a hepatic vein—as structures along path B.

6. EXPLANATION

C. Mirror artifact. When interrogating the right upper quadrant (RUQ), subtle positioning changes of the probe may result in the appearance liver tissue above the diaphragm. Mirror image artifact results from the ultrasound beam reflecting off a dense surface (in this case, the diaphragm) where distal air (in the hemithorax) prevents further transmission. Sound beams will echo off the diaphragm but travel to another point of the diaphragm or liver before returning to the transducer. The ultrasound machine assumes that all echoes have traveled in a straight line to and from the probe and thus plots an image of the liver above the diaphragm. A mirror artifact should always be less hyper echoic than the true anatomic structure it reflects.

REFERENCES

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Sandler MA, Madrazo BL, Maywood CM et al. Ultrasound Case of the Day. *Radiographics*, 1985;7(5): 1025–1028.

Keywords/Tags: Mirror artifact, FAST

Learning Point 6: Mirror image artifact results from the ultrasound beam reflecting off a dense surface where the distal media prevents further transmission.

7. EXPLANATION

B. It is a property inherent to the shape of the emitted ultrasound beam. Conceptually, the ultrasound beam exits the transducer at approximately the same width of the transducer, then narrows as it approaches the focal zone of the probe only to then widen again distal to the focal zone. The distal beam may in fact be wider than the actual width of the transducer. This distal beam may generate detectible echoes that will be displayed on the screen as if they came from the original narrow beam (Figure 3.26a).

Clinically, beam-width artifact may be seen when a structure that should be anechoic—such as the bladder—appears to contain peripheral echoes (Figure 3.26b). When recognized during scanning, image quality can be improved by adjusting the focal zone to the level of interest and by placing the transducer at the center of the desired object.

REFERENCES

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Scanlan K. Sonographic artifacts and their origins. *AJR Am J Roentgenol*. 1991;156(6):1267–1272.

Keywords/Tags: Beam-width artifact, artifact

Learning Point 7: Beam-width artifact is an inherent property of the ultrasound beam and can be mitigated by adjusting the focal zone.

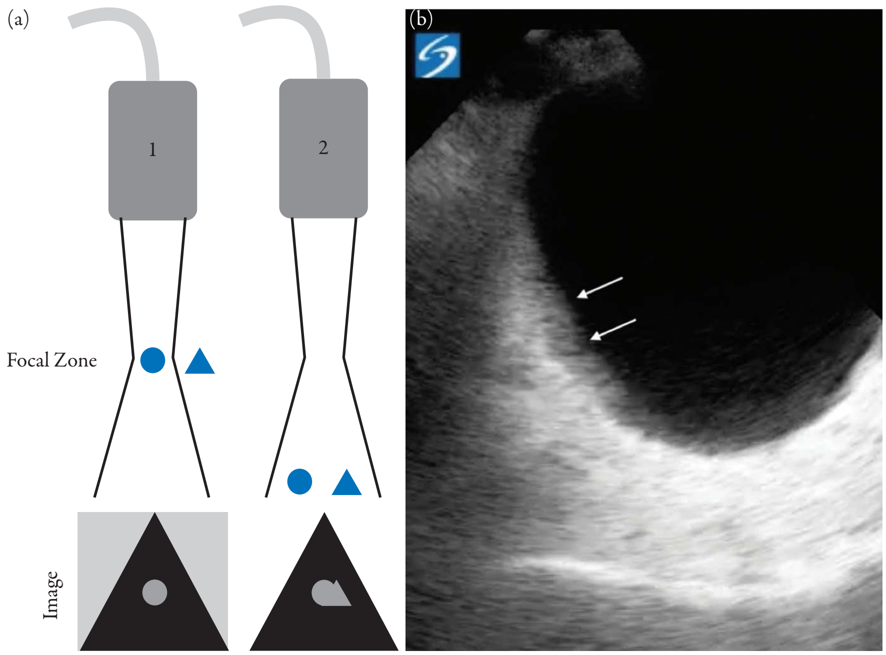

Figure 3.26 (a) **Beam width artifact.** In the images on the right (2), the object of interest is deep to the focal zone. Thus, the widened sound beam hits both the object and adjacent structures, and their echoes are incorporated into one image. The adjacent structure appears on the edge of the structure itself. If the structure of interest is within the focal zone (1), the echo and the translated image will show the structure without overlap from adjacent structures. (b) **Beam width artifact in bladder.** In this view, air from adjacent bowel is seen within the lumen (arrows) of the superior wall of the bladder in this sagittal view. This is due to beam width artifact, which can be minimized by centering the image on the wall as well as increasing the focal zone.

8. EXPLANATION

B. Side-lobe artifact. Side lobes are multiple beams of low-amplitude energy that projects radially from the main beam axis at the footprint of the probe. Strong reflectors in the path of these low-energy/off-axis beams may create echoes detectable by the transducer (Figure 3.27).

REFERENCES

Feldman MK, Katyal S, Blackwood MS. US artifacts. *RadioGraphics*. 2009;29(4):1179–1189.

Scanlan K. Sonographic artifacts and their origins. *AJR Am J Roentgenol*. 1991;156(6):1267–1272.

Keywords/Tags: Side-lobe artifact, artifact

Learning Point 8: Side-lobe artifact is due to strong reflectors from off-axis beams that project radially from the main ultrasound beam.

9. EXPLANATION

C. Reverberation artifact. In simplified terms, the ultrasound machine assumes that an echo returns to the transducer after a single reflection. In the presence of two highly reflective surfaces, echoes generated from the ultrasound beam may be repeatedly bounced back and forth. This repeated bouncing results in a display image of sequential echoes at an increased distance from the transducer. The echo returning after a single reflection is displayed on the screen in the correct location. Sequential echoes will take longer to return to the transducer and therefore these delayed echoes will be shown at an increased distance from the transducer (Figure 3.28).

The image from the question shows a thoracic ultrasound with A-lines, which are reverberations of the area between the skin layer and pleural interface. While each A-line specifically is the reverberation of the pleural lining, the area between the A-lines is the area between the skin and pleural interface.

REFERENCES

Feldman MK, Katyal S, Blackwood MS. US artifacts. *RadioGraphics*. 2009;29(4):1179–1189.

Noble VE, Nelson B. Fundamentals. In: Noble VE, Nelson B, eds. *Emergency and Critical Care Ultrasound*. 2nd ed. New York, NY: Cambridge University Press; 2011:1-21.

Keywords/Tags: Reverberation/ring down artifact, artifacts

Learning Point 9: Describe how reverberation/ring down artifacts occur.

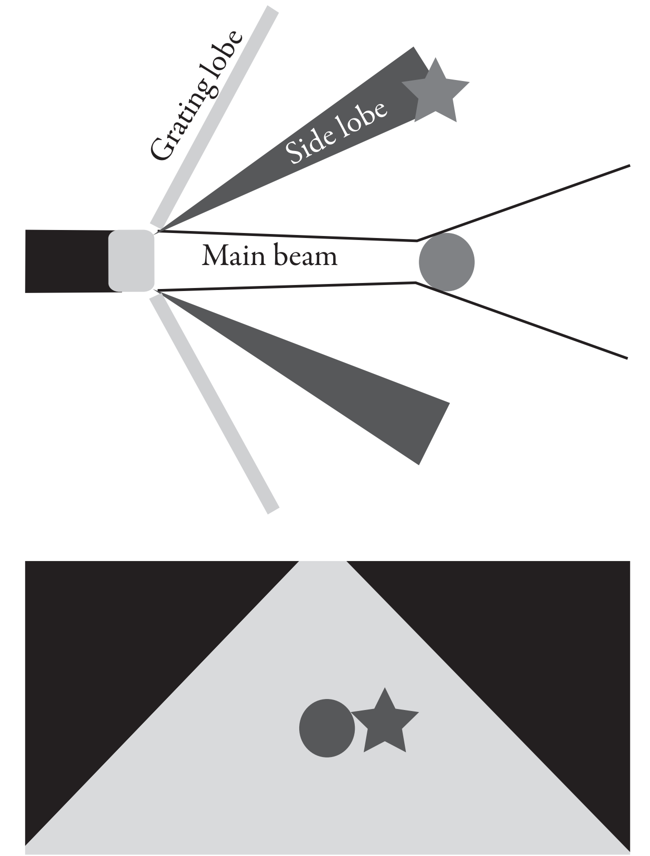

Figure 3.27 **Illustration of side lobe artifact.** Along with a main beam that follows a direct course, each ultrasound beam is accompanied by low-energy, off-axis beams that emanate radially from the main beam. These are called grating and side lobes. The echoes from the off-axis beams, if they return to the transducer, may carry information of structures that are not within the view of the main beam. However, the transducer translates these structures as if they were from the main beam. In this illustration, the main beam encounters the circle, while the side lobe encounters the star. Both structures are then translated on the screen as if they were encountered by the main beam.

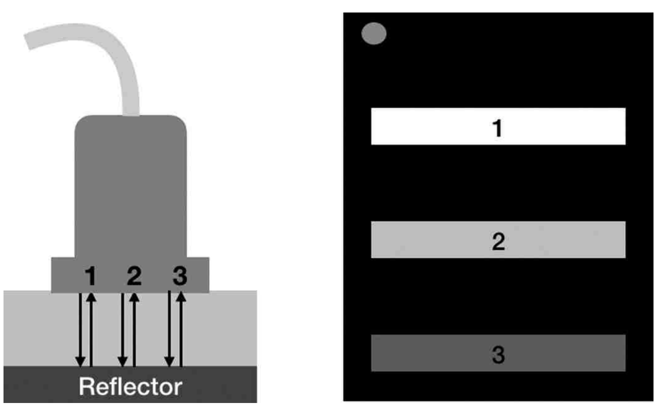

Figure 3.28 **Illustration of reverberation artifact.** Sound waves reverberate between 2 bright reflectors. In this case, it is the skin and the pleural lining (left). Each reverberation (1, 2, 3) is translated as an identical but increasingly attenuated line, each equally spaced (right). The distance between the lines is the distance between the two reflecting surfaces.

10. EXPLANATION

A. Twinkle artifact. Color Doppler is typically used to evaluate blood flow in an area using ultrasound. Imaging a reflective object (such as calculi or foreign body) using color Doppler may result in the appearance of turbulent flow. This appears to be caused by the rough reflective surface of the calculus splitting the ultrasound beam pattern by multiple surface reflections. These reflections from a single surface are interpreted as movement and therefore assigned the blue-red color patterns seen. Color Doppler twinkling artifacts are now understood to be a helpful adjunct to the diagnosis of calcified lesions such as the parenchymal kidney stone in this case.

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Lee JY, Kim SH, Cho JY, Han D. Color and power Doppler twinkling artifacts from urinary stones: clinical observations and phantom studies. *AJR Am J Roentgenol*. 2001;176(6):1441–1445.

Rahmouni A, Bargoin R, Herment A, Bargoin N, Vasile N. Color Doppler twinkling artifact in hyperechoic regions. *Radiology*. 1996;199(1):269–271.

Keywords/Tags: Twinkle artifact, artifacts

Learning Point 10: Define twinkle artifact.

11. EXPLANATION

B. Aliasing artifact. In both spectral and color flow imaging, the velocity scale setting is crucial to the display of signals. Aliasing is related to the fact that both of these imaging modalities use pulsed sound beams. Each pulse is timed to allow for the prior pulses' echoes to return and is governed by the pulse repetition frequency (PRF). If the frequency of the Doppler shift exceeds half the PRF (also known as the Nyquist limit), ambiguous or *aliased* signals are produced. The machine is unable to tell either the velocity and/or direction of flow due to aliasing (Figure 3.29).

Spectral tracing typically shows a wraparound effect while color aliasing projects the color of turbulent flow (typically blue-green) within central areas of higher laminar velocity. Aliasing can be avoided by increasing the velocity scale (which also increases the PRF) or by changing the baseline setting. Using a lower ultrasound frequency will also reduce the frequency shift, which will reduce the probability of aliasing. Switching to continuous wave Doppler (CWD) will also avoid aliasing as the velocity ranges exceed that of PWD. However, the velocities of the entire sampling path are displayed, and not just a sample volume. Increasing

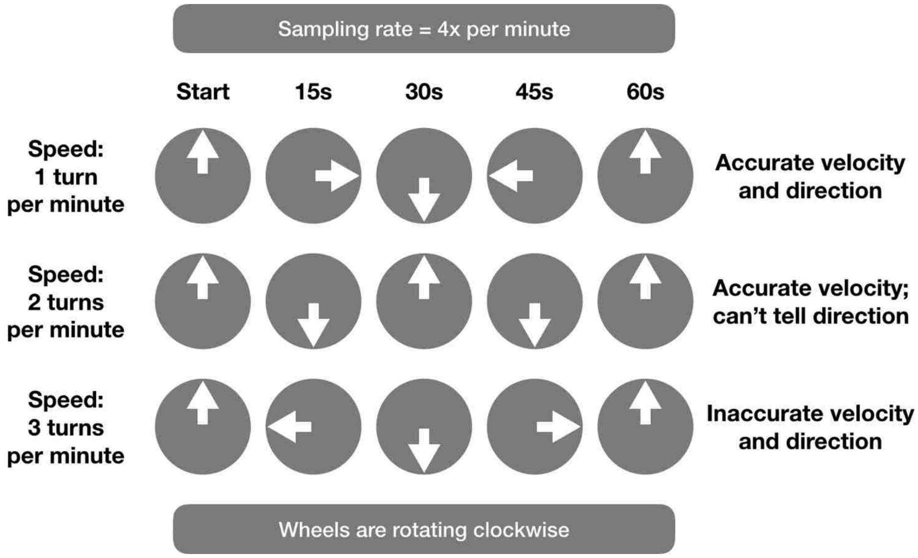

Figure 3.29 **Illustration of aliasing using a wheel concept.** Assume that all wheels are rotating in a clockwise fashion but at variable speed. If the sampling rate is fixed at 4 times per minute, the top wheel will be seen rotating in clockwise direction and it's velocity will be accurate at 1 turn per minute. The middle wheel has a velocity of 2 turns per minute. However, at the fixed sampling rate, the velocity estimated will be correct, but no directionality can be assessed, since the wheel can be moving clockwise or counterclockwise. The bottom wheel spins at three rounds per minute. Using the fixed sampling rate, the wheel will appear to rotate counterclockwise at a speed of 1 turn per minute. Increasing the sampling rate to 5 times per minute will accurately determine the speed and directionality of the middle wheel. Increasing the sampling rate to 7 times per minute will accurately sample all wheel directions and velocities. The sampling rate conceptually is the pulse repetition frequency.

the insonation angle will reduce the Doppler shift, and therefore reduce aliasing, but will lead to a more imprecise velocity estimation.

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Keywords/Tags: Aliasing, artifacts, Nyquist limit

Learning Point 11: Aliasing occurs in Doppler imaging when the frequency shift exceeds the Nyquist limit. It leads to incorrect directionality and/or velocity estimation.

12. EXPLANATION

C. Anisotrophy. Unlike other solid organs in the body, when imaging compact fibrillar structures such as muscle, tendon, ligament, or nerves, the echo displayed is highly dependent on the angle of incidence (or insonation angle). When the ultrasound beam hits a fibrillar structure in an off-perpendicular insonation angle, the organized fibrils may reflect the majority of the insonating beam away from the transducer, therefore there is no returning echo and the image is hypoechoic. This hypoechoic or anechoic appearance may falsely signify pathology such as tendinopathy or bursitis. The maximum return echo occurs when the insonating angle is perpendicular to the long axis of the structure of interest. Imaged in this fashion, fibrillar structures should display as hyperechoic.

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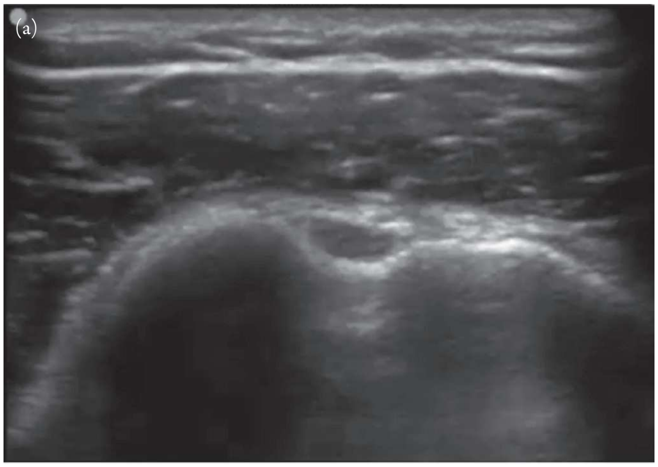
Fornage BD. The hypoechoic normal tendon: A pitfall. *J Ultrasound Med*. 1987;6(1):19–22.

Keywords/Tags: Anisotropy, artifacts

Learning Point 12: When visualizing anechoic or hypoechoic structures on soft tissue or superficial imaging, tilt or fan the transducer to avoid anisotropy.



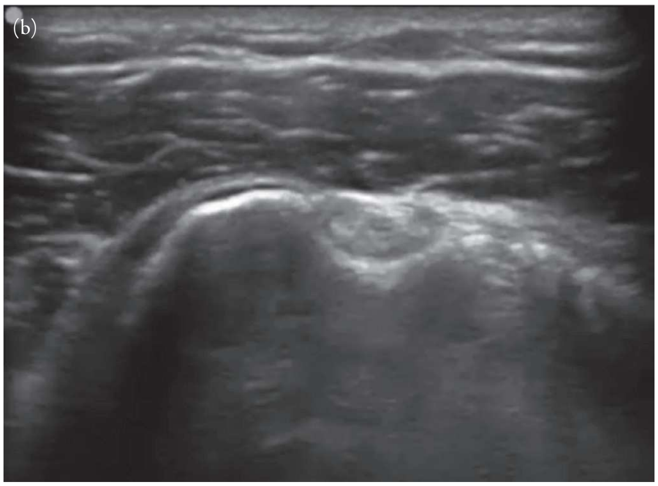


Figure 3.30 **Anisotropy of the biceps tendon.** In the image on the top (a), the long head of the biceps tendon is not visualized. Rather, there is an anechoic appearance that suggests fluid and absence of the tendon. However, by slightly tilting the transducer, the hyperechoic tendon is visualized (in B) without surrounding fluid. This is an example of anisotropy, which can be seen with many structures including: tendons, nerves, ligaments, muscle, myocardium, and pleural lining.

13. EXPLANATION

B. Figure 3.8b (CWD). Standard ultrasound imaging consists of transmitting pulses of ultrasound waves followed by a listening time for returned echoes to process into images displayed on the screen. Delayed echoes are presumed to return from deeper structures, thus allowing for spatial mapping of the resultant image. The percentage of time spent transmitting sound waves is known as the duty factor. More specifically, the duty factor is the duration of the pulse divided by the interval between pulses. For non-Doppler applications like 2D or B-mode and M-mode, they range from 0.1% to 1%. PWD applications can have duty factors up to 5%. In CWD, a form of spectral Doppler, a single crystal continuously transmits sound waves whereas an adjacent crystal listens along the line of interrogation, essentially resulting in a duty factor of 100%. This allows for continuous detection of flow and measurement of high velocities. The disadvantage is that without pulsed sound, the depth at which velocities originate cannot be determined. In addition, since each pulsed wave will impart energy on tissue by heating and mechanical distortion, Doppler applications should be used only when indicated and according to the ALARA principle.

M-mode (motion) uses pulsed ultrasound along a single line of interrogation and displays progression over time. PWD is a form of spectral Doppler that measures flow at a sample volume that the operator selects using the gates on the screen. The disadvantage of this mode is that high-velocity echoes may be represented inaccurately due to aliasing. Color Doppler is able to use pulsed ultrasound to detect flow in the entire field of interrogation. Color Doppler is capable of detecting directionality whereas power Doppler simply detects presence of motion and is the preferred method for assessing low flow states.

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Edelman SK. Describing pulsed waves. In: Edelman SK. *Understanding Ultrasound Physics*. 1st ed. Woodlands, TX: Baker & Taylor; 2003:45–67.

Keywords/Tags: B-mode, M-mode, color Doppler, power Doppler, pulse wave Doppler, CWD, duty factor

Learning Point 13: Duty factor or duty cycle is the percentage of time that the transducer actually transmits sound waves versus total time transmitting and detecting for returned echoes. Doppler applications have higher duty factors and should be used sparingly.

14. EXPLANATION

C. M-mode. M-mode (motion-mode) ultrasound uses standard pulsed ultrasound but focuses interrogation along a single line of interrogation. As time passes, all points along the line are spatially displayed over time, allowing for the detection of motion at any single point along the line. By focusing on a single line of echoes, the temporal resolution can be improved. This method is preferred for the measurement of fetal heart rate as it emits less energy to developing tissues than Doppler modes. B-mode ultrasound does not display motion over time; rather it provides a dynamic assessment of the entire scan plane. Both color and power Doppler emit high energy to developing tissue, violating the ALARA principle and exposing sensitive fetal tissue to a high TI.

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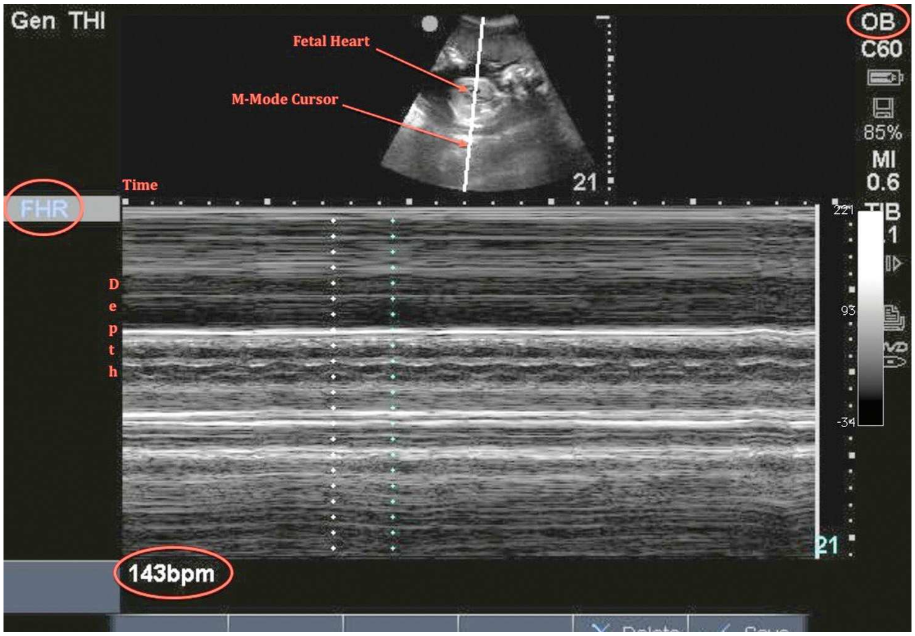

Figure 3.31 **M-mode to assess fetal heart rate.** Note that "OB" preset is selected, and the fetal heart rate (FHR) calculation is engaged. M-mode plots a tracing of the scan line (in the 2D image at the top) over time, with the interval between each bold box signifying 1 second. By setting the gates between two peaks or troughs, a FHR of 143 beats per minute is obtained. Note that the y-axis signifies depth for both the M-mode tracing and the 2D image.

Edelman SK. Describing pulsed waves. In: Edelman SK. *Understanding Ultrasound Physics*. 1st ed. Woodlands, TX: Baker & Taylor; 2003:45–67.

Keywords/Tags: M-mode

Learning Point 14: M-mode allows for display of all motion along a single line of echoes, with increased temporal resolution as compared to 2D.

15. EXPLANATION

C. The number of moving particles, not velocity. Power Doppler is a form of nondirectional color Doppler. It detects the presence of a Doppler shift without characterization of speed or direction. In power Doppler, the signal strength (as seen by increasing intensity) is directly proportional to the number of moving particles.

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McDicken T. Difference between colour Doppler velocity imaging and color power Doppler. *Eur J Echocardiogr*. 2002;3(3):240–244.

Keywords/Tags: Color Power Doppler

Learning Point 15: Color power Doppler is more sensitive at detecting flow compared to conventional color Doppler, since it detects the presence of moving particles and not the velocity or direction of flow.

16. EXPLANATION

C. Pulsed wave Doppler. Spectral Doppler displays quantitative graphing of flow velocity over time. Both CWD and PWD are subtypes of spectral Doppler. PWD (Figure 3.8c) allows for measurement of flow velocity along a single spatial point or sample volume and would therefore be the ideal mode for measuring flow velocity along the mitral inflow tract. PWD is not suitable for use while measuring high-velocity flow, especially when it exceeds the Nyquist limit (PRF/2) as this leads to aliasing and subsequent erroneous measurement. CWD (Figure 3.8b), as the name implies, does not use intermittently pulsed ultrasound and thus is not limited by PRF in its possible range of measurements. CWD is ideal for evaluation of high-velocity flow, for instance in assessing pressure gradients when valvular stenosis or regurgitation is suspected. CWD lacks range specificity and cannot tell the precise location from which echoes originate. Color Doppler (Figure 3.8d) and power Doppler (Figure 3.32) do not allow for accurate measurement of flow velocity.

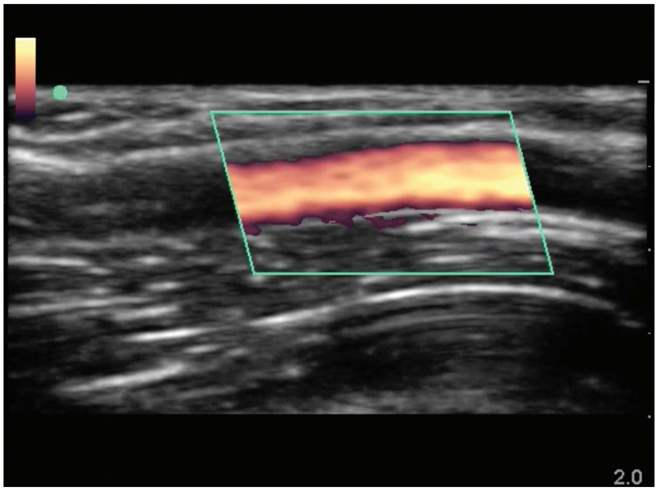

Figure 3.32 **Color Power Doppler (CPD) of the radial artery.** Note that there is no velocity or directionality in CPD, but just the presence and amount of moving particles. This is inferred by the amplitude of the frequency shift- the higher the amplitude, the greater the signal intensity, and thus the greater amount of moving particles.

REFERENCE

Edelman SK. *Understanding Ultrasound Physics*. Woodlands, TX: Baker & Taylor; 2003.

Keywords/Tags: Pulsed wave Doppler, continuous wave Doppler, spectral Doppler

Learning Point 16: PWD measures velocities from a narrow range of velocities at a fixed sample volume. CWD measures a wide range of velocities from all points along a sampling path or line. PWD is prone to aliasing while CWD is subject to range ambiguity.

17. EXPLANATION

C. Right image because the indicator should point cephalad. Ultrasound probes have an indicator marker on one side of the probe, usually a raised dot or line, that marks the leading edge of the ultrasound beam. This marker correlates with the orientation marker on the ultrasound screen. For most bedside scans (apart from procedural scans), the probe marker should point toward the patient's right or toward his or her head. Situating the ultrasound machine at the top of the bed allows the clinician to face the patient and the screen. It also aligns the probe orientation with the screen orientation.

Choosing the correct probe for each scan is essential but would not help to correct this image. M-mode is an ultrasound modality that shows movement over time. Power Doppler is an ultrasound modality that shows the strength of a Doppler signal in color—it is helpful when assessing small vessels or low-flow states.

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Keywords/Tags: Indicator marker, FAST

Learning Point 17: The transducer's indicator generally should point toward the patient's head or right.

18. EXPLANATION

B. Sliding. Moving the probe in the long axis across the body is described as sliding and would be the correct movement to go from visualizing Morrison's pouch to checking above the diaphragm in the right upper quadrant. Of note, rocking the probe toward the contralateral shoulder will often help to visualize the diaphragm, but this is not an answer choice. Fanning is motion along the short axis of the probe while maintaining a stable position on the body. Compression (changing the pressure of the ultrasound probe on the body) will bring the image into better focus and can show deeper structures. Sweeping is moving the probe in the short axis across the body. Rotation is a physical rotation (clockwise or counterclockwise) of the probe over a stable position on the body.

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Keywords/Tags: Cardinal movements, FAST

Learning Point 18: Fanning, sliding, compression, and rotation are cardinal movements of probe.

19. EXPLANATION

D. Hyperechoic, anechoic. On ultrasound, bone (arrow) has a bright white rim and darker shadowing beneath. The bright white rim of bone is hyperechoic (brighter) compared to surrounding structures. The pleural effusion (*) appears

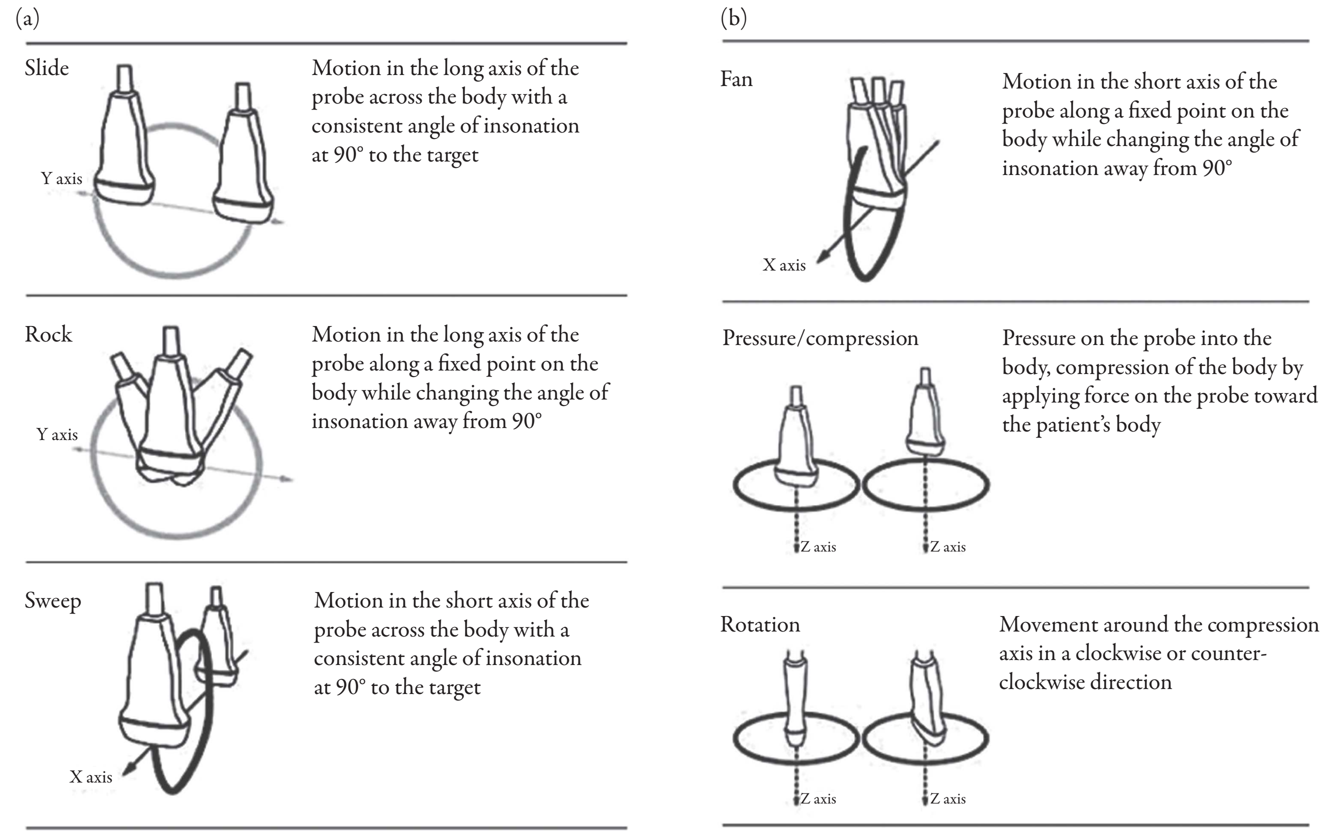

Figure 3.33 (a) **Probe movements.** Sliding is moving the probe along its long axis, while rocking the probe refers to angling the scan plane along the long axis but maintaining the probe's position on the body. Sweeping refers to translating the probe along its short axis. Adapted from Table 1 of Bahner DP, Blickendorf JM, Bockbrader M. Language of transducer manipulation: codifying terms for effective teaching. *J Ultrasound Med.* 2016;35(10):183–188. (b) **Probe movements.** Fanning or tilting the probe refers to angling the scan plane along the short axis but maintaining the probe's position on the body. Compression refers to applying pressure to the body with the probe to bring deeper structures closer to the probe for imaging. Rotation is performed along the z-axis, or the axis created by the probe itself. Adapted from Table 1 of Bahner DP, Blickendorf JM, Bockbrader M. Language of transducer manipulation: codifying terms for effective teaching. *J Ultrasound Med.* 2016; 35(10):183–188.

as black (anechoic) on ultrasound. Hypoechoic structures are darker grey than surrounding structures. Isoechoic structures are the same greyness as surrounding structures.

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Keywords/Tags: Pleural effusion

Learning Point 19: Echoes displayed on the screen are described as, "anechoic," "hyperechoic," "hypoechoic," and "isoechoic."

20. EXPLANATION

D. Change the preset to "abdominal." Ultrasound machines come programmed with a variety of tissue preset settings that are often helpful in improving the quality of ultrasound images. These presets change how the image is displayed and involve adjusting the contrast, frame rate, and post-processing done to the obtained image by the ultrasound machine. In addition, calculation packages may differ, depending on the preset selected. The depth on this image is already sufficient to see the important structures, so increasing the depth would not improve the image quality. FAST exams can be done with the phased array probe or the curvilinear probe, but the high-frequency linear probe would not provide sufficient depth to obtain this image.

REFERENCE

Kelley K, Rose JS, Bair AE. Fundamentals of ultrasound. In: Cosby KS, Kendall JL, eds. *Practical Guide to Emergency Ultrasound.* 2nd ed. Philadelphia, PA: Lippincott, Williams & Wilkins; 2014:10–19.

Keywords: presets, frame rate, calculations

Learning Point 20: Tissue-specific presets optimize imaging by adjusting gain, contrast, temporal resolution, and post-processing.

21. EXPLANATION

C. Linear. The different ultrasound probes that are used commonly have different properties that help us to visualize different structures and easily do procedures.

- *The linear probe* is the best choice for visualizing superficial structures and is commonly used for obtaining venous access or arterial lines, performing nerve blocks, or visualizing musculoskeletal structures. This probe generates short wavelength, high frequency (5–10 mHz) sound waves. This probe is best used for visualizing structures that are <5cm deep (Figure 3.34a).
- *The curvilinear probe* is commonly used for abdominal scanning. The crystals are arranged in a curved/convex shape and produce an ultrasound beam that is wide and deep. This probe produces longer wavelength, lower frequency (2–5 mHz) waves, which allows you to visualize structures up to 25 cm deep. However, resolution is less clear compared to the linear probe, and thus this is not the correct probe to use when looking at superficial structures (i.e., for vascular access) (Figure 3.35b).
- *The cardiac/phased array probe* has a smaller footprint than the curvilinear probe and is thus ideal for cardiac ultrasound because it can fit between the rib spaces. This is a low frequency probe (1–5 mHz). This probe differs in that there is sequential (or phased) activation of the piezoelectric crystals, which results in a wider field of view than one might expect from the small footprint of the probe. This probe does not provide clear resolution for superficial structures and thus is not the correct choice for vascular access.
- *The intracavitary probe* is used commonly for transvaginal and prostate scanning and can also be used to look at oral structures (peritonsillar abscesses). This probe has a small, convex footprint and a high frequency (5–10 mHz). It has a wider field of view than the linear probe but similar resolution. The curved shape of this probe makes it less than ideal for vascular access.

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Smith RS, Fry WR. Ultrasound instrumentation. *Surg Clin N Am*. 2004;(84): 935–971.

Keywords: transducers, frequency, footprint

Learning Point 21: The footprint and frequency range of transducers dictate their appropriateness in imaging various structures.

22. EXPLANATION

A. Decrease depth. Adjusting the depth allows the machine to pay attention only to those echoes that give information in the

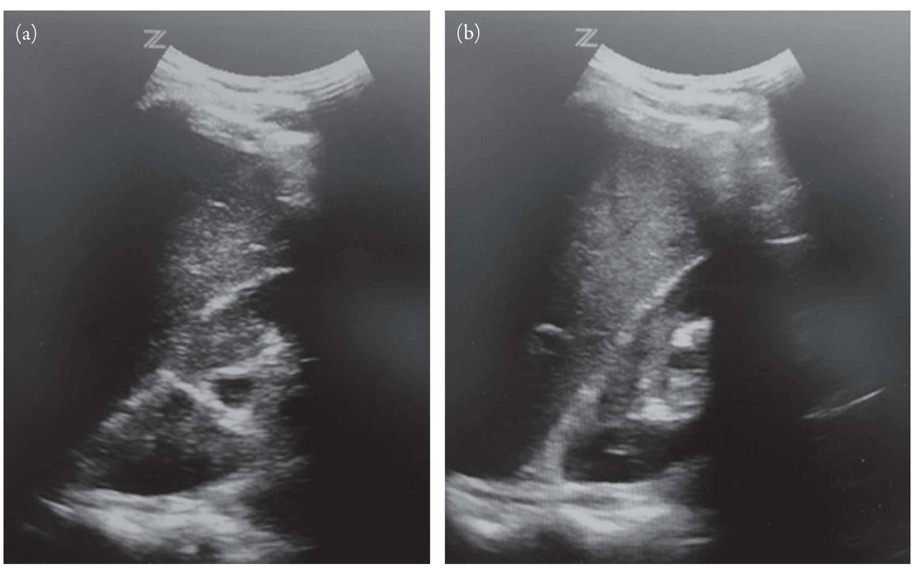

Figure 3.34 **Comparison between two presets for right upper quadrant imaging.** Panel (a) shows the hepatorenal window using aorta preset, while panel (b) shows the same window using abdominal preset. Notice that the aorta preset renders a more granular image, which is due to a decreased frequency setting to allow for visualization of deeper structures like the aorta. The abdominal preset generates a higher resolution image of the liver and kidney.

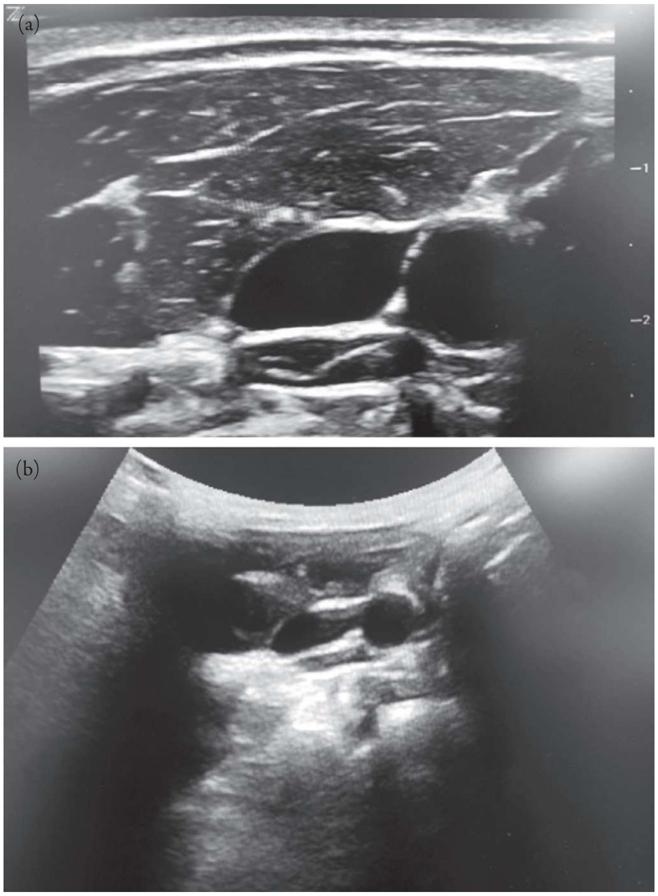

Figure 3.35 (a) **Imaging the neck vessels using a linear transducer.** (b) **Imaging the neck vessels using a curvilinear transducer.** Note the broader field of view and depth, but decreased resolution of the soft tissue, as compared to the linear transducer. Also, since the phased array transducer shares a similar frequency range as the curvilinear, imaging will be similar.

field that you are interest in. Since echoes from a more shallow field take less time to return back to the transducer, decreasing the depth allows for more pulses to be generated and increases both the duty factor and PRF. Because more information is collected, this produces an image with a higher resolution. Adjusting the focal zone to the object of interest also primes the computer to process more echoes in that range of view. This also increases resolution for structures in this focal zone. Gain is appropriate in this image (the anechoic interior of the aorta appears black). The linear probe would not produce good image quality at this depth. The phased array probe would also not produce the best images of the abdominal aorta.

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Keywords: duty factor, PRF, focal zone, depth

Learning Point 22: Optimizing depth and focal zone will increase resolution of the image.

23. EXPLANATION

C. Decrease the gain. The gain on this image is too high and produces a very bright image that makes it challenging to differentiate hyper- and hypo-echoic structures. It would be easy to miss the small amounts of hypo-echoic free fluid in this image with the gain turned up so high. Another important consideration when setting the gain on an image is TGC. You can change the degree of gain (brightness) in the near, mid, and far-field section of your image. As time passes from ultrasound wave transmission, the amplitude of the wave decreases. Thus, deeper structures will appear darker even if they have the same echogenicity as more superficial structures. To adjust for this, you can change the TGC—by increasing the gain in the mid- and far-fields of the image, they will appear the same echogenicity as more superficial structures. Thus, this compensates for the decreased amplitude sound waves returning from deeper structures. The curvilinear probe is the correct choice for this image. The depth is set appropriately.

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Edelman SK. Pulsed echo instrumentation. In: Edelman SK. *Understanding Ultrasound Physics*. 1st ed. Woodlands, TX: Baker & Taylor; 2003:211–234.

Lawrence JP. Physics and instrumentation of ultrasound. *Crit Care Med*. 2007;35(8 Suppl):S314–S322.

Keywords/Tags: depth, wave amplitude, gain, attenuation

Learning Point 23: Gain adjustment allows for increasing or decreasing the brightness of various portions of the image.

24. EXPLANATION

A. Decrease the color gain. Think of the color gain like a "volume knob" for your color flow image. The color gain setting adjusts the way the ultrasound machine displays data returning to the machine. Often the controls are the same as the TGC or gain knobs. Color gain cannot amplify signal that does not exist, but if set incorrectly it can distort how the color flow data is presented. If the color gain is set too low, true flow may be underestimated or not visualized at all. If the color gain is set too high, noise will appear and may

obscure the Doppler signal of interest as seen in this image. To appropriately set the color gain, place the sample box in an area where you do not anticipate there will be flow. Turn the gain up until random color speckles appear. Then turn the color gain down until they just disappear. Decreasing the scale or wall filter may lead to more erroneous flow signals. A lower frequency probe will not address this issue.

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Keywords/Tags: Color Doppler, knobology, acquisition, color gain

Learning Point 24: Color gain, similar to normal gain, can be adjusted to display the intensity of flow in Color Doppler.

25. EXPLANATION

D. Normal blood flow away from the probe. This is an apical five-chamber window with color Doppler placed on the left ventricular outflow tract. The color scale map on your ultrasound screen shows the color assignment given to mean Doppler shift velocities. As you adjust the color scale, the numbers displayed on this map will change. By convention, negative Doppler shifts (those away from the transducer) are displayed in blue, and positive Doppler shifts (those toward the transducer) are displayed in red. This can be recalled using the mnemonic BART (blue away, red toward). More important, you always have the color map available to you when you are in a color mode to show you how flow in different directions will be displayed on the screen.

Aortic regurgitation (AR) is incorrect because the mitral valve is closed, signifying systole. Also, AR flow will be headed toward the left ventricular apex, or red. Aortic stenosis will demonstrate nonlaminar flow or acceleration of flow, which is seen as green-yellow on color Doppler.

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McDicken T. Difference between colour Doppler velocity imaging and color power Doppler. *Eur J Echocardiogr*. 2002;3(3):240–244.

Keywords/Tags: Color Doppler, cardiac, knobology, acquisition, color maps

Learning Point 25: On color Doppler, flow away from the probe (or top of the screen) is blue, while flow going toward the probe is red. A helpful mnemonic is BART (blue away, red toward).

26. EXPLANATION

A. Increase the scale. Aliasing is an artifact that occurs when the velocities you are observing exceed the set velocity scale. This scale defines your sampling rate or PRF. In this image there is a mitral regurgitation jet directed away from the probe. The high-velocity negative Doppler shifts exceed the scale and "wrap around" to appear positive. Thus, on the image there is a mixing of yellow into the predominantly blue jet. There are several ways to reduced aliasing:

1. Increase the scale.
2. Adjust the baseline (on PWD).
3. Select an alternate imaging window at a more superficial depth. When the depth is decreased sound waves take a shorter time to travel from the probe to the tissues and back again and thus the PRF is increased.
4. Switch to a lower frequency probe. Higher frequency sound waves produce higher Doppler shifts.
5. Switch to CWD. Aliasing occurs with both color flow Doppler and PWD modes because sound waves are pulsed. It does not occur with CWD because certain crystals are always "listening."

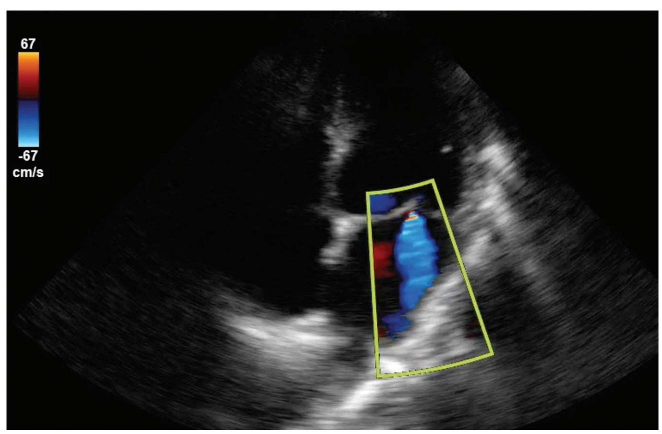

Figure 3.36 **Mitral regurgitation without aliasing on color Doppler imaging.** The scale has been increased in another example of mitral regurgitation so that there is no turbulent flow visualized. Note that the magnetic resonance jet is directed toward the posterior-lateral left atrial wall. In the setting of suspected endocarditis, this would imply a coaptation failure of the anterior mitral valve leaflet.

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Quinones MA, Otto CM, Stoddard M, Waggoner A, Zoghbi WA; Doppler Quantification Task Force of the Nomenclature and Standards Committee of the American Society of Echocardiography. Recommendations for quantification of Doppler echocardiography: a report from the Doppler Quantification Task Force of the Nomenclature and Standards Committee of the American Society of Echocardiography. *J Am Soc Echocardiogr*. 2002;15(2):167–184.

Keywords/Tags: Color Doppler, knobology, acquisition, color gain

Learning Point 26: Aliasing occurs when the sampling rate or PRF, is set too low for velocities observed.

27. EXPLANATION

A. Switch to CPD. CPD detects the presence of flow independent of direction or velocity of flow. There is flow detected when you switch to CPD (Figure 3.37).

CPD has several advantages:

1. It is more sensitive to measuring low velocities in smaller vessels.
2. It is angle independent allowing detection of slower velocities.
3. There is no potential for aliasing.
4. Because it is angle independent, it may be useful in imaging tortuous vessels.

Because of its increased sensitivity, these advantages come at the expense of increased flash artifact, which occurs because of increased motion sensitivity. This artifact will occur when there is tissue motion or the probe is not held completely still. Increasing the scale or decreasing the gain would make slow flow more challenging to see.

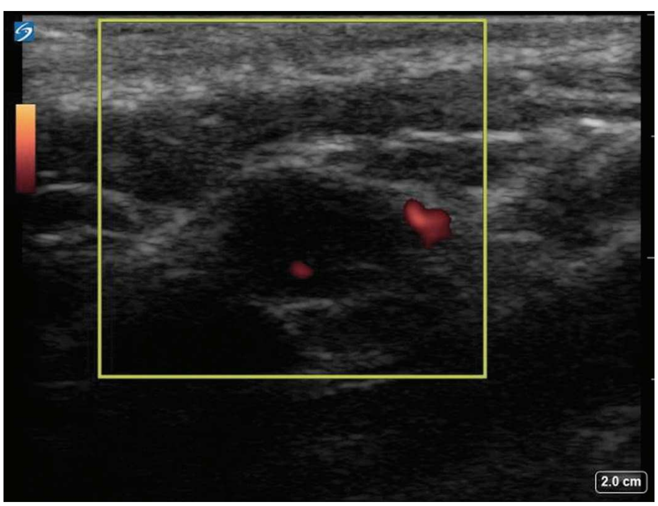

Figure 3.37 **Hyperechoic soft tissue mass on color power Doppler.** There is flow detected in the hilum and periphery of this presumed lymph node.

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McDicken T. Difference between colour Doppler velocity imaging and color power Doppler. *Eur J Echocardiogr*. 2002;3(3):240–244.

Keywords/Tags: Color power Doppler, knobology, acquisition

Learning Point 27: Color power Doppler (CPD) should be used to evaluate for flow in a low-flow vessel or mass.

28. EXPLANATION

B. Increasing the wall filter. Color bleeding occurs because the walls of the vessel and the tissues immediately adjacent to the vessel are also moving, although at a slower velocity than the red blood cells within the vessel. The wall filter eliminates a set range of low velocity around the baseline that will not be displayed on the screen. If set too high, the wall filter may decrease your ability to detect slow velocity flow that is of interest. If set too low, normal anatomic motion within in the tissues will be displayed as seen here. In this image the color box is steered appropriately.

Wall filter, along with color gain and scale, can be adjusted to optimize flow. In Figure 3.38, the wall filter is set at medium to evaluate flow within this dilated portal vein.

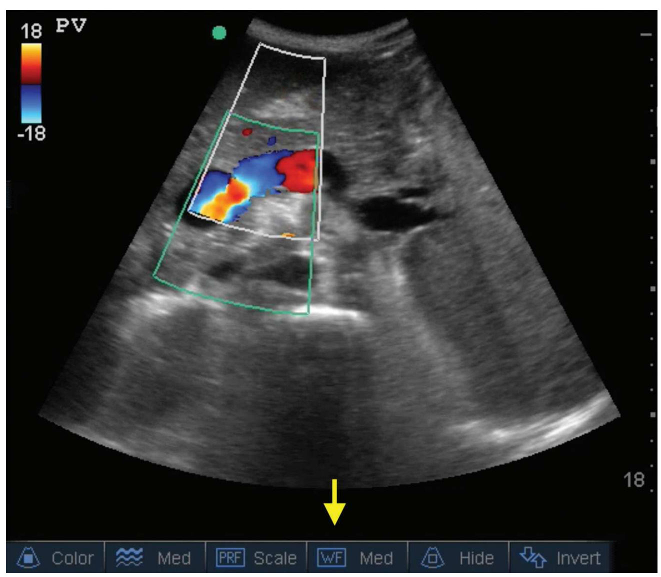

Figure 3.38 **Portal vein with optimized wall filter.** The wall filter (WF; arrow) is set at medium. In some point-of-care ultrasound machines, the wall filter setting may be directly linked to the scale or pulse repetition frequency setting.

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Keywords/Tags: Wall filter, knobology, acquisition, vascular ultrasound

Learning Point 28: Wall filter adjustment affects the low range of velocities sampled in both color and spectral Doppler.

29. EXPLANATION

A. Angle dependence of Doppler ultrasound. Doppler shift is maximal when motion you are evaluating is parallel to the sound beam (at 0° or 180°). This angle between the flow and the sound beam is called the insonation angle. As the angle changes from this parallel orientation, the percentage of true velocity that is measured decreases and depends on the cosine of the insonation angle.

According to the Doppler equation $V = \Delta fC/2f_o\cos\theta$, where:

V = velocity

Δf = Doppler frequency shift

C = speed of sound in soft tissue

f_o = original transmitted frequency

θ = the insonation angle

When the flow is exactly perpendicular to the sound beam, as in this case, no Doppler signal is created because the cosine of 90° is 0. As you fan the probe toward or away from you, the flow in the vessel becomes more parallel to the sound beam and can be detected. If you fan the probe slightly toward the elbow as in Figure 3.19b, red color will appear. Remember measuring Doppler signal from flow that is not parallel to the sound beam will always underestimate the true velocity present.

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Keywords/Tags: Color Doppler, Doppler equation, angle dependence, radial arterial line

Learning Point 29: Doppler ultrasound accuracy is affected by the angle of insonation, which is the angle between the ultrasound beam and direction of flow.

30. EXPLANATION

A. Figure 3.20a. The color box should be steered such that the ultrasound beam-to-blood flow angle, or insonation angle, is ≤60°. The Doppler shift is most reliable at this angle and less. The sonographer can also rock or angle the transducer to achieve this insonation angle (Figure 3.39). The PWD gate should be placed in the center of the vessel. Remember that only one plane of the vessel is seen on your screen, and it is also important that you have positioned your probe to obtain a central cut of the vessel and are not imaging near the wall, as this will affect your velocity measurements. The size of the gate should allow the sampling area to occupy the central one-third of the vessel. The correction line within the gate can be adjusted so that it is parallel to the flow of blood.

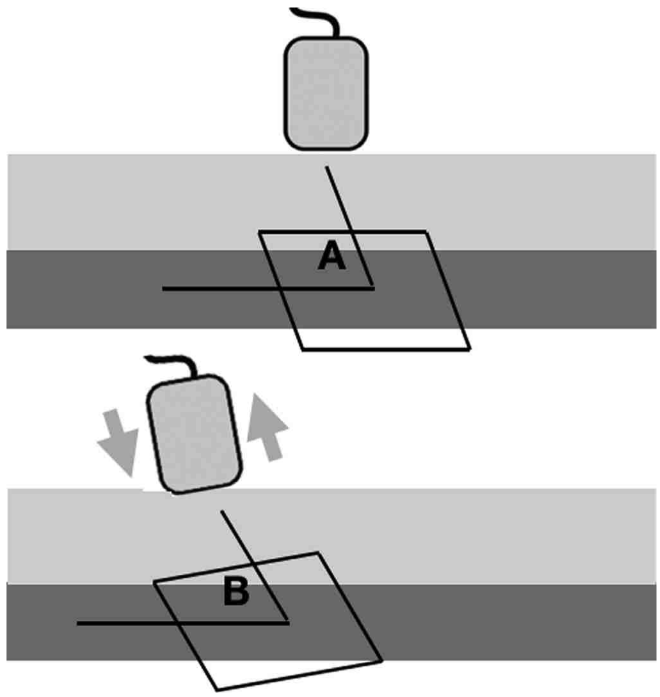

Figure 3.39 **Techniques to reduce the insonation angle on vascular Doppler imaging.** In vascular imaging, the insonation angle (aka Doppler angle) should be at 60° or less to effect maximal Doppler shift. Normally, though, the ultrasound beams are perpendicular to arterial flow. However, steering the angle (a) will help to reduce the insonation angle. In addition, angling or rocking the transducer (b) will further reduce the insonation angle to below 60°.

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Terslev L, Diamantopoulos AP, Møller Døhn U, Schmidt WA, Torp-Pedersen S. Settings and artefacts relevant for Doppler ultrasound in large vessel vasculitis. *Arthritis Res Ther*. 2017;19:167.

Keywords/Tags: PW Doppler, knobology, acquisition, steering

Learning Point 30: Correct measurement on CWD and PWD depends on gate positioning, gate size, and steering adjustment.

31. EXPLANATION

B. Left ventricular outflow tract during systole 40 cm/s, carotid artery 50 cm/s, testicular arteriole 4 cm/s, IVC 0.4 cm/s. Ultrasound machines are capable of detecting a wide range of velocities from flow across a stenotic aortic valve—which can exceed 400 cm/s—to flow within testicular arterioles, which ranges from 1 to 5 cm/s. Having a basic understating or normal range of blood velocities on various anatomic structures can help you to ensure that your scale is set appropriately and that you recognize pathologic flow when it is present. In general, if you select the correct preset the ultrasound machine will optimize the color scale to detect normal anatomic flow within a structure.

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Pozniak MA, Allan P, eds. *Clinical Doppler Ultrasound*. Edinburgh, UK: Churchill Livingstone; 2013:26–39.

Keywords/Tags: Color Doppler, knobology, acquisition

Learning Point 31: Normal range of blood flow is from 0.4 cm/s (IVC) to 50 cm/s (carotid artery).

32. EXPLANATION

A. Switch modes to CWD. In this PWD tracing, high negative Doppler shifts exceed the set velocity scale, causing aliasing. To correct this we can shift the baseline upwards to show more negative velocities since we are only interested in the tricuspid regurgitation jet. Increasing the scale will also allow us to better visualize this higher velocity flow. The settings for the PWD scale and baseline are presented on the Y-axis of the PWD tracing. The numbers at each end of the scale represent the highest velocities that can be measure before aliasing will occur. If we have maximized these adjustments, and aliasing is still present, we can switch to CWD, which is the preferred mode for this application and is not subject to aliasing. The image with corrected tracing using CWD is shown in Figure 3.40.

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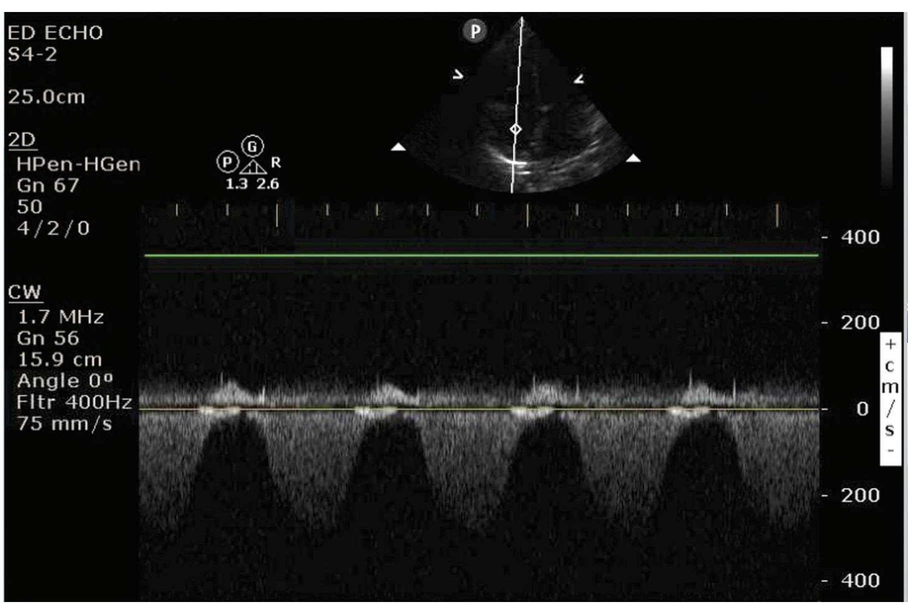

Figure 3.40 **Right ventricular systolic pressure assessment using continuous wave Doppler.**

Keywords/Tags: Pulsed wave Doppler, knobology, acquisition, mitral inflow velocities

Learning Point 32: Adjusting the baseline, scale, and wall filter can optimize color and spectral Doppler tracings.

33. EXPLANATION

A. Small and superficial. Recall that color Doppler is a form of PWD. Crystals divide their time sending out pulsed sound waves and listening for returning waves. The closer an object is the less time it takes sound waves to travel between the probe and the tissues, thus ultrasound pulses can be sent more frequently. A smaller color flow box also improves the frame rate and color resolution, as the machine can send more sound waves to a smaller area of interest.

REFERENCE

Edelman SK. Doppler. In: Edelman SK. *Understanding Ultrasound Physics*. 1st ed. Woodlands, TX: Baker & Taylor; 2003:293–328.

Keywords/Tags: frame rate, color Doppler, acquisition

Learning Point 33: Increases in the box size and depth on color Doppler reduces frame rate and imaging quality.

34. EXPLANATION

C. Propagation speed. Sound waves exhibit various acoustic parameters, namely the period, frequency, amplitude, power, intensity, speed, and wavelength. Among these, the speed of the sound wave is the only parameter that remains constant through a given medium, regardless of the source. Of note, sound waves travel through air-filled lung at 400 m/s, soft tissue and solid organs at 1400–1600 m/s, and bone at 4000 m/s. The average propagation velocity of sound in tissue, 1540 m/s, is often used in calculations. Wavelength and period are inversely related to frequency within a given medium (Figure 3.41).

Amplitude, power, and intensity are related concepts that are generally dictated by the source, or ultrasound system. Amplitude is often expressed in pressure, density, or decibels. Power is the square of amplitude and is expressed in energy terms, specifically Watts. Intensity is the power divided by the cross-sectional area of the ultrasound beam. Although intensity is mostly unrelated to frequency, it does not remain constant but rather decreases as it travels through a medium relative to the attenuation coefficient.

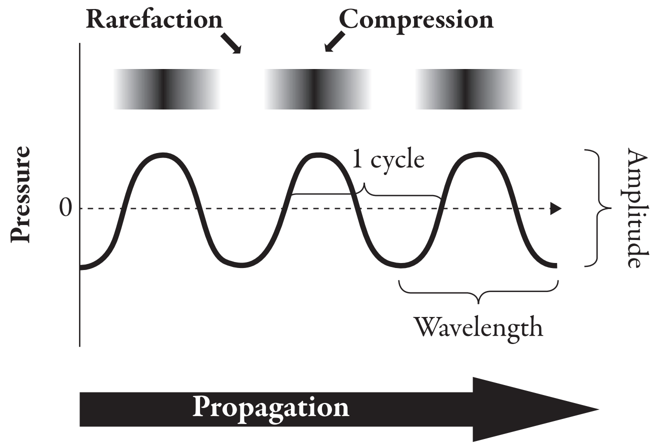

Figure 3.41 **Illustration of a sound wave.** Adapted from Figure 2.1 from, Feigenbaum H, Armstrong WF, Ryan T, Physics and instrumentation. In: Feigenbaum H, ed. *Feigenbaum's Echocardiography*. 6th ed. Philadelphia, PA, Lippincott Williams & Wilkins; 2005:11–45.

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Keywords/Tags: Acoustic parameter, physics, propagation speed

Learning Point 34: The properties of a sound wave are determined by the ultrasound machine and the media they travel through. They include: period, frequency, amplitude, power, intensity wavelength, propagation speed).

35. EXPLANATION

D. Decrease the frequency as attenuation is directly proportional to frequency. Attenuation is a term that describes the weakening of a sound wave as it passes through a medium. This phenomenon results due to a combination of reflection, scattering, and absorption of sound and is measured as a relative difference in amplitude, power, and intensity. Sound frequency and distance of travel (depth) are the two most important variable factors affecting attenuation, and they are both directly proportional to it. The deeper you scan the more sound waves are lost to attenuation. High-frequency sound waves attenuate more than lower frequency sound waves. Increasing the gain only amplifies the signal once it has returned but will not mitigate the effect of attenuation.

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Keywords/Tags: Attenuation, frequency, image resolution, image depth

> **Learning Point 35:** Attenuation is directly related to depth and frequency. Changing to a lower frequency or lower frequency transducer will reduce attenuation.

36. EXPLANATION

B. Bone has a much higher attenuation coefficient. In ultrasound, attenuation is defined as a loss of ultrasonographic energy as it travels through a medium. This occurs by means of three different mechanisms, namely reflection, scattering, and/or absorption of the incident sound wave. Absorption is generally the principal contributor toward attenuation, with reflection and scattering occurring at varying degrees. The amount of attenuation that occurs for each centimeter along the path of the soundwave is known as the attenuation coefficient, and it varies for each medium.

In order of increasing attenuation coefficient, as expressed in decibels per cm depth per frequency (MHz), are: water (0), blood (0.2), fat (0.6), soft tissue (0.7), liver and kidney (~1), muscle (1.3–3.3), bone (5), and air (12).

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Keywords/Tags: Attenuation coefficient, shadowing, absorption, reflection

> **Learning Point 36:** Air has the greatest attenuation, followed by bone, solid organs, and soft tissue. Water and blood have the lowest attenuation.

37. EXPLANATION

C. The relative impedance mismatch is greater in aerated lung, resulting in increased reflection. Impedance is a term defined as the resistance of a specific medium to the passage of sound. It is determined primarily by multiplying the density of the medium with the speed of propagation. Along the path of an ultrasound wave, the degree of reflection is related to the relative impedance mismatch between

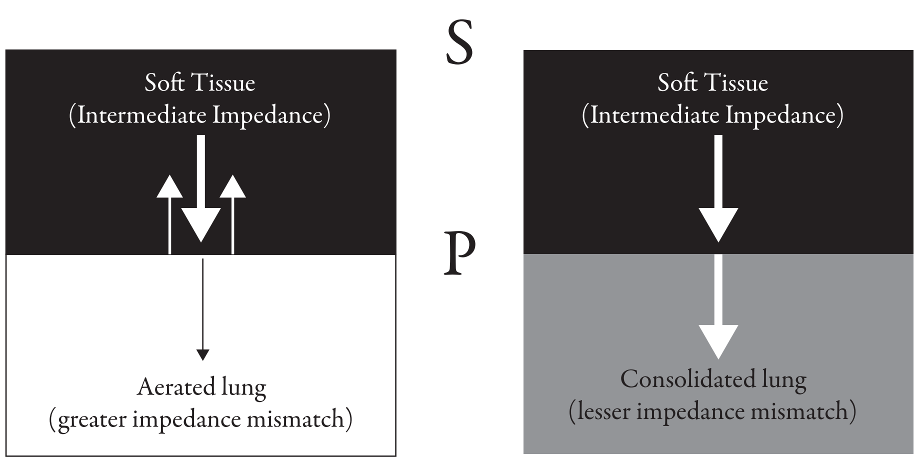

Figure 3.42 **Impedance and A-lines in Lung.** In normal lung, sound waves will travel from the skin (S) to the pleura (P), but due to the high impedance mismatch of the aerated lung, will either be absorbed or reflected back to the skin. This iterative process leads to the generation of a-lines. In consolidated lungs or those with alveolar-interstitial syndrome, the water content allows for transmission of sound waves into the lung parenchyma, leading to a decrease or absence of a-lines, and either hepatization of lung or presence of B-lines.

two bordering media. Air transmits sound waves at higher velocity than soft tissue, hence the increased impedance and subsequent reflectivity.

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Keywords/Tags: Impedance, reflection

Learning Point 37: Define impedance and describe how it determines the amount of sound that is reflected to the probe and the image that is acquired.

4.

RESUSCITATIVE ULTRASOUND

Ishan Mehta, Dale Jun, Stephanie Guo, and Igor Barjaktarevic

QUESTIONS

1. A 63-year-old woman with a recent diagnosis of locally advanced breast cancer undergoing neoadjuvant chemotherapy is admitted after having had an unwitnessed syncopal episode at home earlier on the day of presentation. Her primary complaint is fatigue and shortness of breath with exertion. She is admitted to the telemetry unit for further work-up. On hospital day 1 while ambulating in the unit, the patient collapses. She had progressive bradycardia with pauses leading to PEA prior to the event. A code blue is called, and advanced cardiac life support is initiated. After several minutes, there is return of spontaneous circulation. You perform a point-of-care ultrasound (POCUS) echocardiography and DVT study (Figure 4.1, Videos 4.1 and 4.2).

Based on the available information, what is the next best step in reversing the underlying cause of cardiac arrest?

A. Administer alteplase bolus of 50 mg over 2 minutes.
B. Perform bedside bronchoscopy.
C. Obtain cultures and start empiric broad spectrum antibiotics.
D. Perform emergent pericardiocentesis.

2. A 67-year-old man with a history of coronary artery disease status bypass surgery and obesity is admitted to the hospital with community-acquired pneumonia. On hospital day 3, the patient develops chest pain. On telemetry, frequent premature ventricular contractions and non-sustained ventricular tachycardia are noted overnight. Later in the morning, sustained ventricular tachycardia is noted, and the patient becomes obtunded and pulseless. A code blue is initiated. You are the first physician to respond and see the rhythm strip (Figure 4.2a). After initiating cardiopulmonary resuscitation (CPR), you perform the following POCUS echo (Figure 4.2b, Video 4.3) on a pulse check.

What is the next step in management?

A. Continue CPR and prepare for unsynchronized defibrillation.
B. Continue CPR and follow nonshockable rhythm CPR pathway.
C. Perform immediate endotracheal (ET) intubation and mechanical ventilation.
D. Administer intravenous (IV) lidocaine and monitor response.

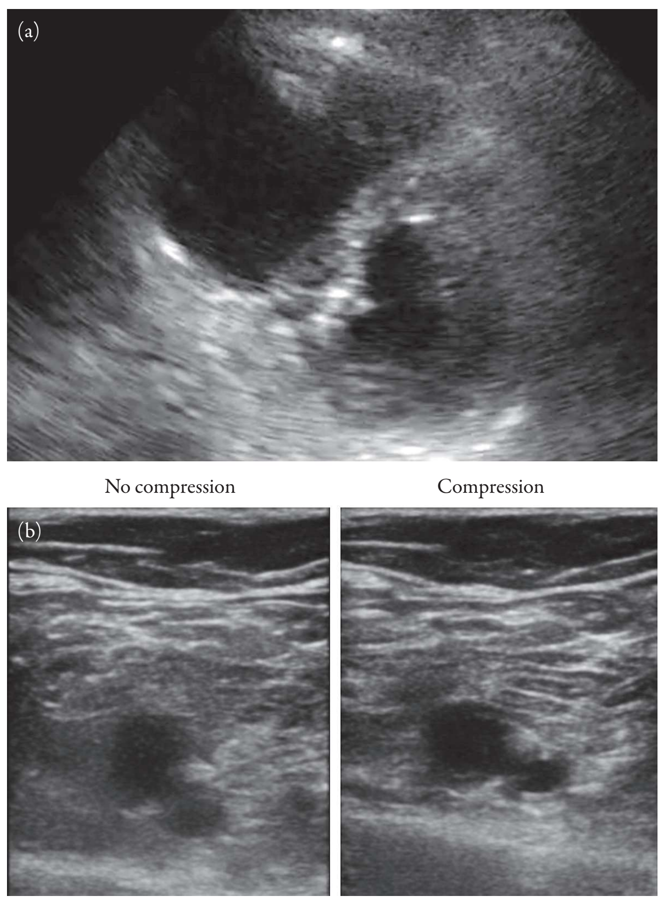

Figure 4.1

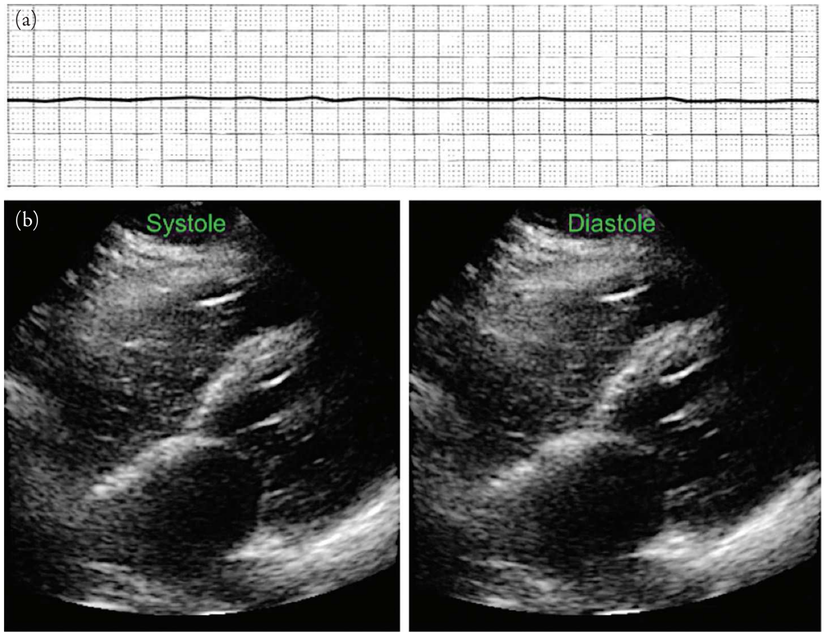

Figure 4.2

3. A 59-year-old man with a history of end-stage idiopathic pulmonary fibrosis is being evaluated for potential lung transplant. He presents for a routine preoperative left and right heart catheterization via right femoral access, which revealed nonobstructive coronary artery disease, preserved left ventricular (LV) function, as well as mildly elevated pulmonary artery pressures with normal pulmonary capillary wedge pressure. Postprocedure, the patient went into v-fib arrest.

Immediate resuscitation per ACLS guidelines was performed, and return of spontaneous circulation (ROSC) was achieved. POCUS was done immediately post-ROSC, and you obtain the following POCUS echo (see Video 4.4 and Figure 4.3).

What is the best next step of management?

A. Lung protective ventilation with inhaled nitric oxide
B. Start IV epoprostenol
C. Administer nalaxone, lung protective ventilation
D. Veno-arterial ECMO

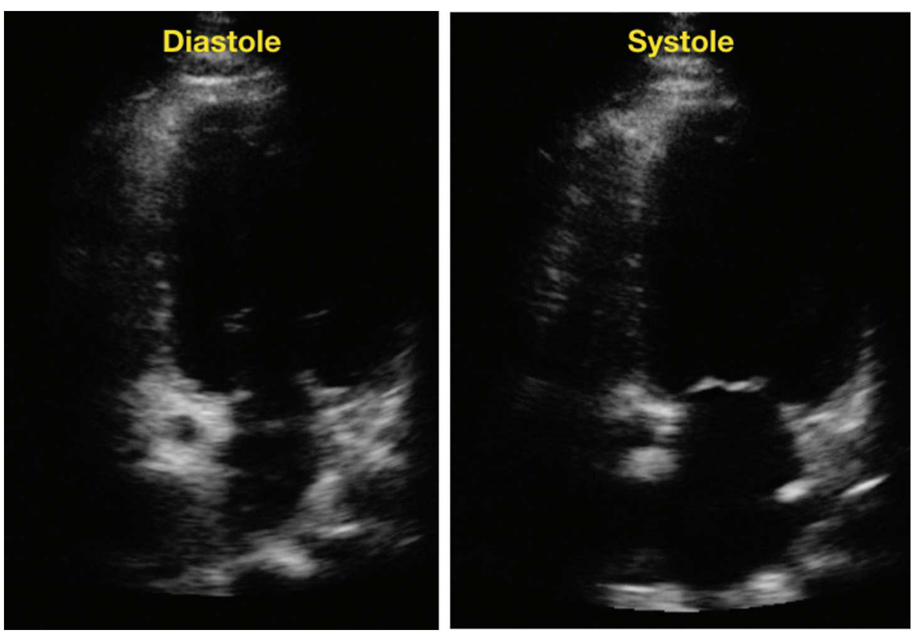

Figure 4.3

Figure 4.4

4. A 22-year-old male professional wrestler with sickle cell anemia (HbSS) and multiple prior episodes of sickle cell crisis presents with worsening left upper quadrant abdominal pain. The patient has no other past medical history. His pain, notably different than his previous episodes of sickle cell crises, has been worsening over several hours. He is started on a patient-controlled analgesia (PCA) pump. Over 30 minutes, the patient becomes progressively altered. As the "rapid response" is called, the patient in now in severe distress. He subsequently becomes hypotensive and unconscious with a narrow complex tachycardia at a rate of 180/s. Within a minute, patient is in PEA arrest. As the ACLS resuscitation protocol is initiated, a quick bedside ultrasound is performed and the abdominal component of ultrasound shows the following finding (see Figure 4.4 and Video 4.5).

What is the next best step in management?

A. Discontinue PCA and monitor.
B. Initiate rapid blood transfusion.
C. Obtain computerized tomography (CT) abdomen immediately.
D. Insert triple lumen central venous catheter.

5. A 45-year-old male with a prior history of heavy alcoholism presents with acute dyspnea and hypercarbia. He is disheveled with evidence of recent vomiting on his face and clothes. In the emergency department (ED), he is initiated on noninvasive positive pressure ventilation with bilevel positive airway pressure (BiPAP) with initial improvement in his blood gas. BiPAP is subsequently discontinued due to severe distress, which over the next 10 minutes progresses into severe hypoxia and PEA arrest. CPR is initiated and ROSC achieved. A rapid ultrasound in shock or hypotension (RUSH) ultrasound is performed. The splenorenal view of the hemothorax shows the following (Figure 4.5a). The patient's chest x-ray (CXR) on admission several hours earlier is also reviewed (Figure 4.5b).

What is the most likely etiology for the ultrasound finding in this case?

A. Spontaneous pneumothorax
B. Esophageal rupture
C. Aspiration pneumonia
D. Pleural malignancy

6. A 46-year-old obese woman with a history of chronic kidney disease presents to the ED with two weeks of progressive oliguria, fluid retention, and dyspnea on exertion that has progressed since its insidious onset, now present at rest. In addition, her symptoms have been accompanied by chest discomfort. Her vital signs are notable for blood pressure measuring 80/60 mmHg, and EKG showing a regular, narrow complex tachycardia at 110 beats per minute. POCUS echocardiogram images are obtained for initial evaluation (see Figure 4.6, Video 4.7, and Video 4.8).

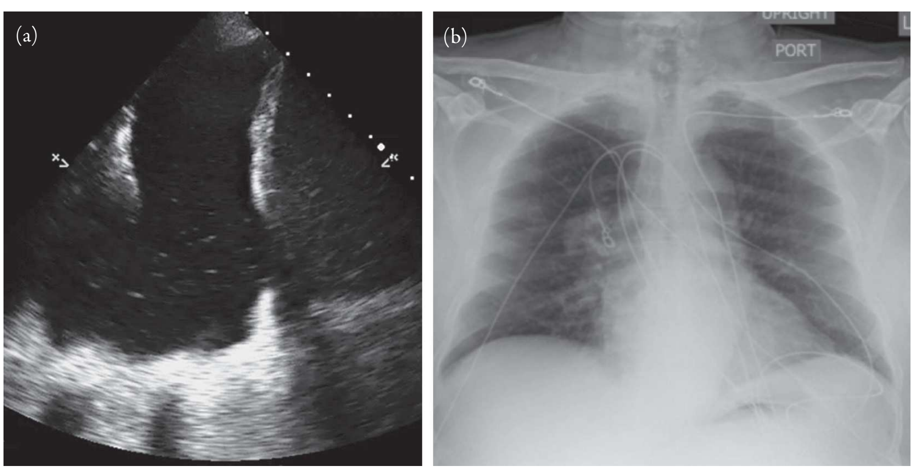

Figure 4.5

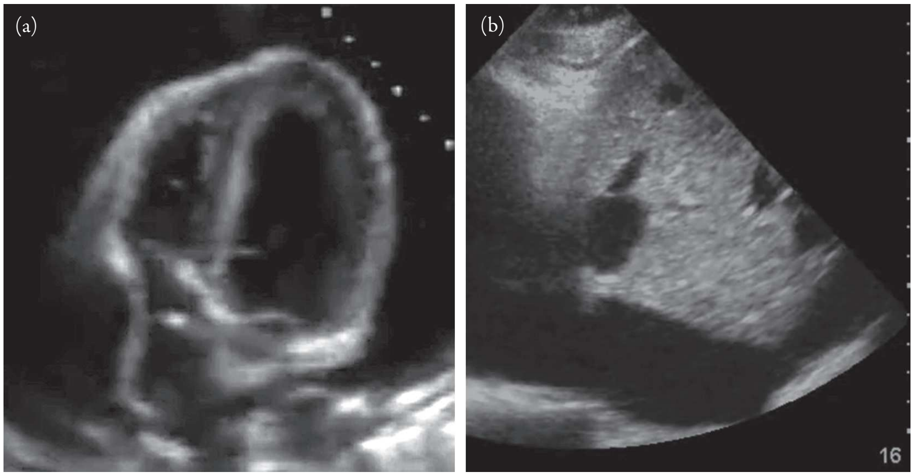

Figure 4.6

What is the best first step in the management?

A. Administer IV diuretics.
B. Start unfractionated heparin drip.
C. Administer IV volume repletion and inotropic support while awaiting pericardiocentesis.
D. Perform thoracentesis.

7. A 72-year-old male with a history of diabetes, hyperlipidemia, and chronic back pain recently had a normal transthoracic echocardiography (Video 4.9) as part of his preoperative workup for back surgery.

On post-op day 1, the patient developed acute left-sided chest pain radiating to the mid-back. An EKG showed new ST depressions in antero-lateral lead distribution. The patient developed acute hypotension. You perform the following POCUS echo (see Figure 4.7, Video 4.9, and Video 4.10).

What is the most likely cause of patient's clinical decline?

A. Post-op hemorrhagic shock
B. Sepsis
C. Pulmonary embolism
D. Acute coronary syndrome

8. A 55-year-old man is admitted to the plastic surgery service for a left lower extremity wound sustained from a burn. He underwent skin grafting in the popliteal fossa and immobilization of the left leg. On post-op day 2, the patient developed retrosternal chest pain and dyspnea while on room air. Subsequently, he develops a mild fever and moderate respiratory distress. A rapid response is called. Initial vital signs obtained include blood pressure of 98/62 mmHg, heart rate of 110 beats per minute, respiratory rate of 24, oxygen saturation of 88% on 15 liters per minute of oxygen. An EKG shows sinus tachycardia without evidence of ischemia. The patient is transferred to the intensive care unit (ICU), and the following bedside echocardiogram image is obtained (see Figure 4.8, Video 4.11, and Video 4.12).

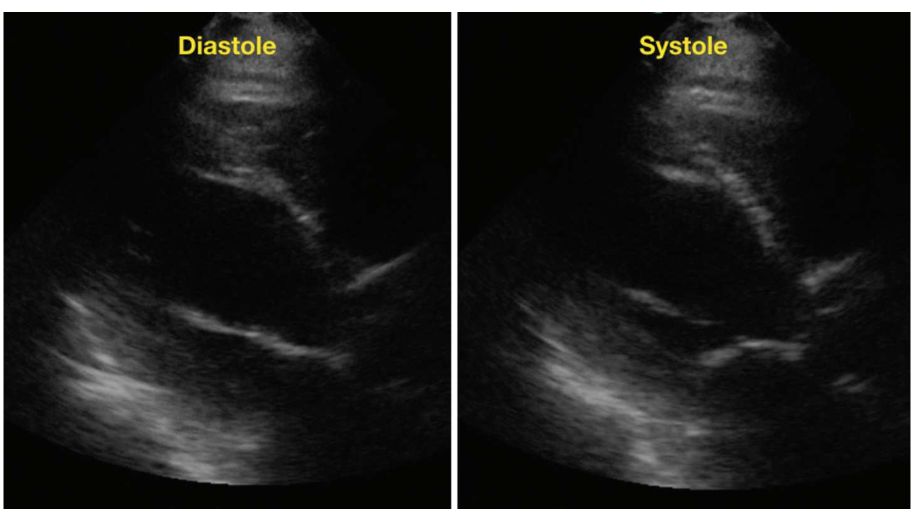

Figure 4.7

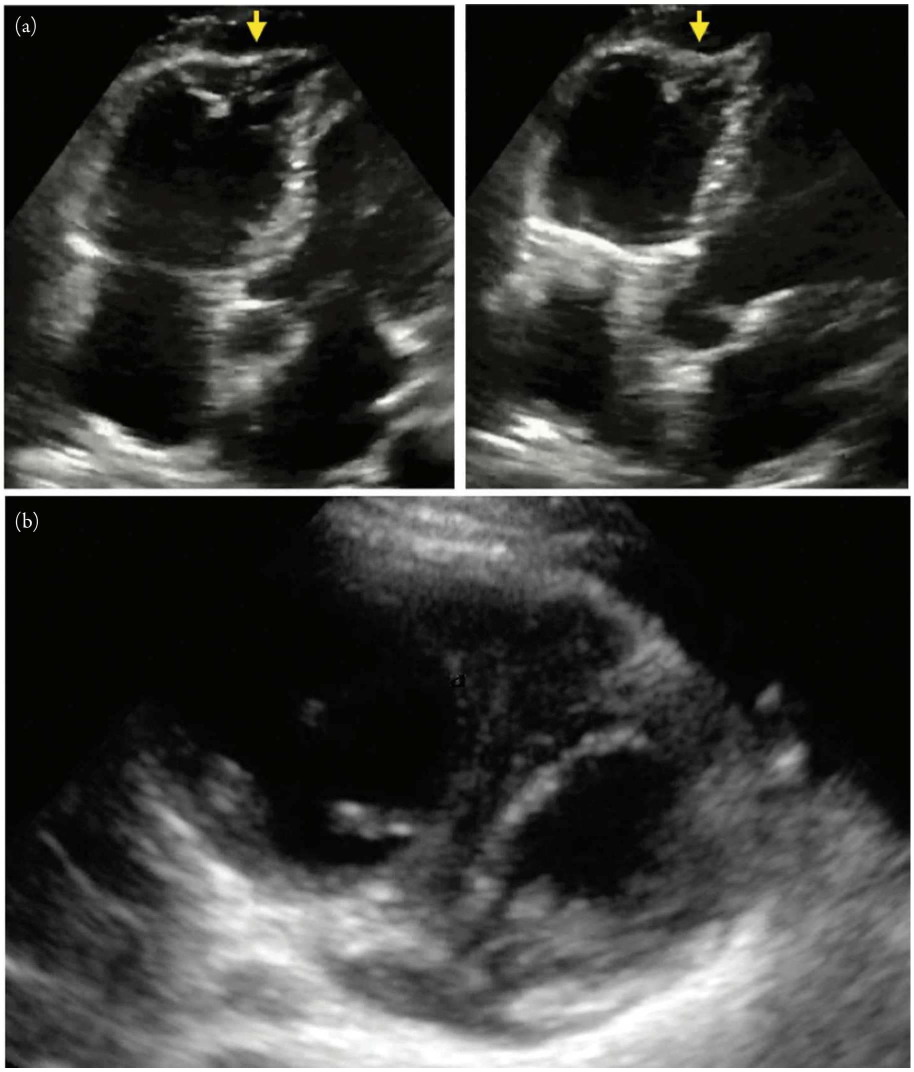

Figure 4.8

What is the next best step in diagnosis and management?

A. Perform pericardiocentesis.
B. Start IV unfractionated heparin while awaiting STAT CT chest angiography.
C. Emergent left heart catheterization for potential percutaneous coronary intervention.
D. Obtain CT abdomen/pelvis with contrast.

9. A 65-year-old female with a history of chronic kidney disease (baseline creatinine 2.3) and breast cancer, currently on chemotherapy, presents to the ED with acute dyspnea that began the night prior at rest. She denies any chest pain. She has no prior history of lung disease and is a lifelong non-smoker. On exam, the patient is in moderate respiratory distress, tachycardic to 110, and hypoxic to 83% on room air that improves to 92% with supplemental oxygen. Blood pressure is normal. The rest of her exam is unremarkable. The patient's CXR is shown in Figure 4.9.

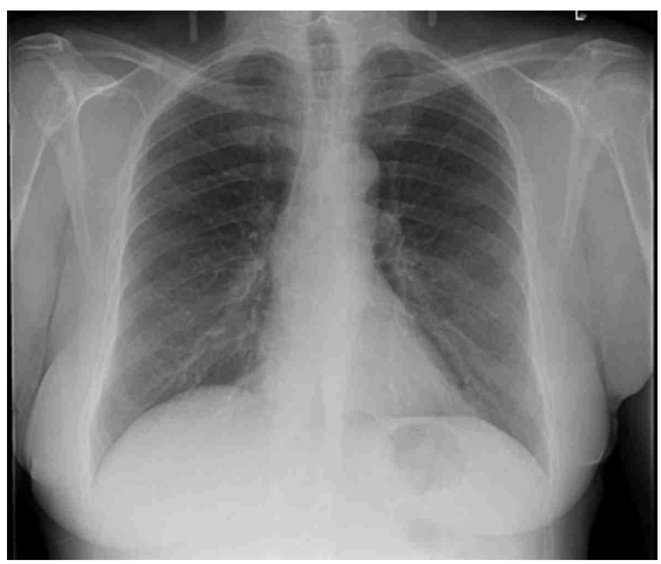

Figure 4.9

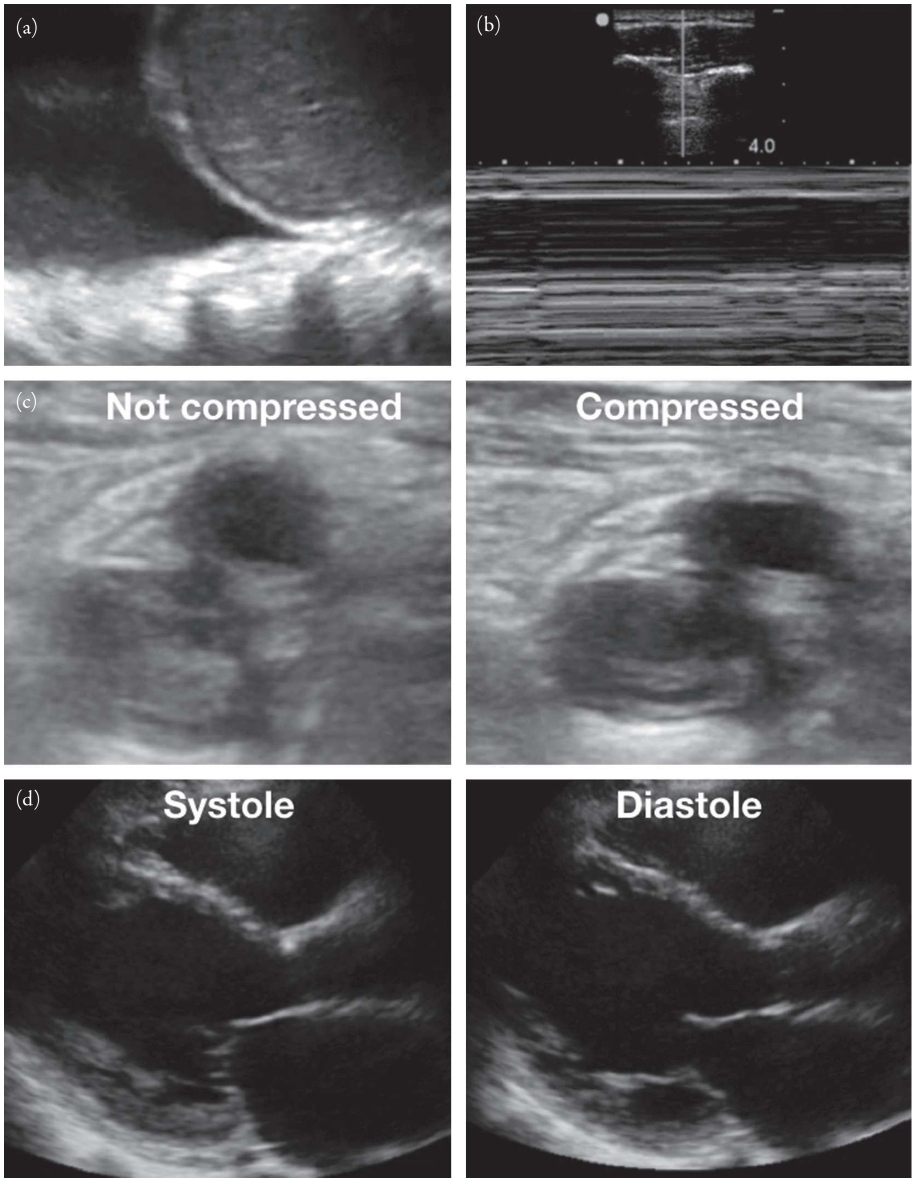

Figure 4.10

Which of the following bedside ultrasound images most likely explains this patient's clinical picture?

A. Figure 4.10a
B. Figure 4.10b
C. Figure 4.10c
D. Figure 4.10d

10. A 67-year-old male who is a former smoker and has a history of diabetes mellitus, coronary artery disease status post percutaneous coronary intervention, and well-controlled chronic obstructive pulmonary disease (COPD) reported a sudden onset of chest pain 3 days ago that resolved spontaneously; as such, he did not seek care at that time. Today, he presents to the ED with similar symptoms. He is tachycardic and mildly hypotensive with a harsh systolic murmur at the apex. Initial labs are notable for an acute kidney injury with creatinine (Cr) of 1.9 mg/dL (baseline 1.3). B-natriuretic peptide (BNP) and troponin are pending. A portable CXR shows asymmetric right greater than left upper lobe interstitial edema (see Figure 4.11).

You perform the following POCUS echo (see Figure 4.12 and Video 4.13).

In addition to initial steps targeting clinical stabilization of this patient, which intervention may be necessary to help this patient's recovery?

A. Start oral steroids.
B. Initiate of hemodialysis.
C. Consult cardiothoracic surgery consultation for possible mitral valve repair/replacement.
D. Initiate IV antibiotics.

Figure 4.11 From Figure 1A of Kashiura M, Tateishi K, Yokoyama T, et al. *Acute Med Surg*. 2017;4(1):119–122. doi:10.1002/ams2.234.

11. A 60-year-old man with a history of hypertension and substance abuse presents with acute onset of chest pain and shortness of breath. He had initially been seen in clinic for severe hypertension of 220/110, but his arrival blood pressure in the ED is 95/70 mmHg. The patient is in extremis and appears diaphoretic. A bedside ultrasound assessment is performed (see Figure 4.13 and Video 4.14).

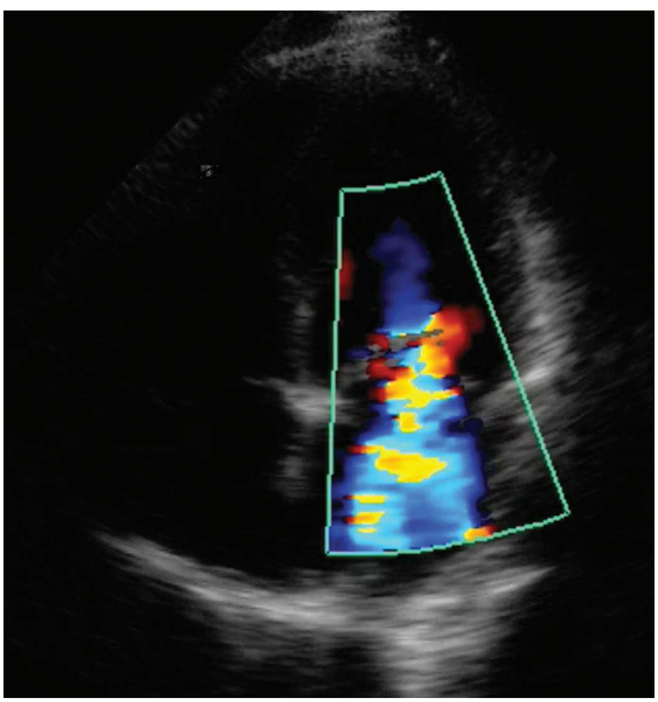

Figure 4.12

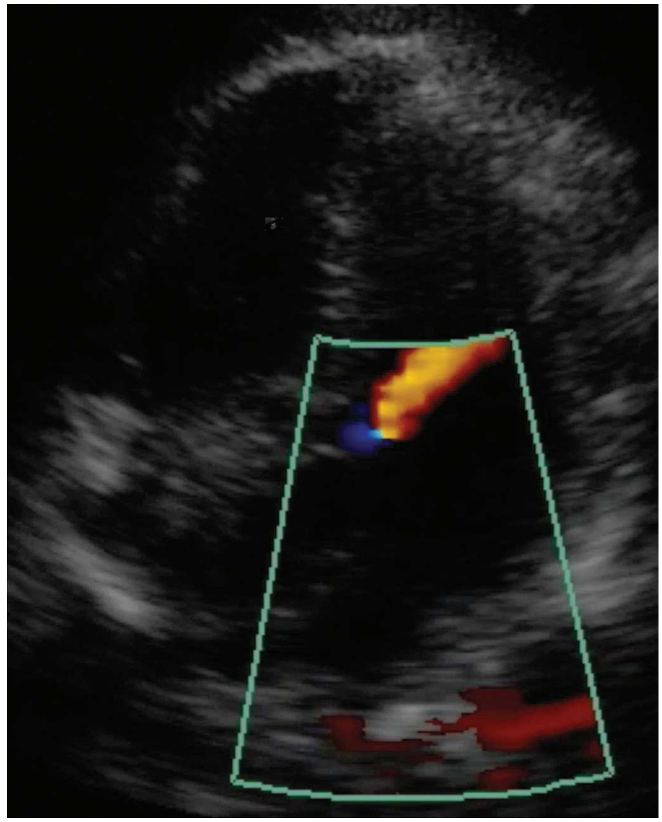

Figure 4.13

Assuming the findings are acute, which of the following studies can be obtained for further diagnosis?

A. STAT TEE
B. CT angiography of the chest
C. Left heart catheterization
D. Right heart catheterization

12. An 80-year-old female resident of a skilled nursing home with dementia and severe kyphosis presents with lethargy, fevers, productive cough, and shortness of breath. She is found to have a multifocal pneumonia, started on broad-spectrum antibiotics, and admitted to the medical wards. On hospital day 2, the patient requires progressively more oxygen and becomes hypotensive despite several IV fluid boluses. Soon after the patient is transferred to the ICU. Her ICU vital signs show blood pressure of 70/40, pulse of 120, respiratory rate of 30 times a minute, and oxygen saturation 91% on high flow nasal cannula on 80% fraction of inhaled oxygen and flow of 60 liters per minute. After confirming full code status with the patient's immediate family, the decision is made to perform ET intubation. During direct laryngoscopy, you are unable to obtain an adequate view of the vocal cords, requiring use of head-adjustment maneuvers and Bougie-assisted intubation. Following the intubation, the patient intermittently

Figure 4.14

has nonsustained ventricular tachycardia on the monitor, indistinct waveform on the pulse oximeter, and immeasurable blood pressure via noninvasive cuff. Though you auscultate symmetric breath sounds, you decide to quickly confirm correct placement of the ET tube by POCUS.

What does the ultrasound image in Figure 4.14 show?

A. Endotracheal intubation
B. Esophageal intubation
C. Tracheo-esophageal fistula
D. None of the above

13. A 72-year-old woman with unknown past medical history was brought in by ambulance from her skilled nursing facility due to altered mental status. The patient presents with scant nursing notes and no other documentation. On exam, she is altered, febrile to 38.7°C, and hypotensive with a mean arterial pressure of 52 mmHg and heart rate of 90. She weighs 72 kilograms. In the ED, she is started on empiric antibiotics and resuscitated with 2 liters of normal saline but remains hypotensive with increasing oxygen requirements. Urinalysis suggests a urinary tract infection. POCUS shows the cardiac and lung findings in Figure 4.15 and Videos 4.15 and 4.16.

What is the next best step in management of this patient's hypotension?

A. Continue aggressive IV fluid resuscitation with repeated fluid boluses.
B. Start heparin drip.
C. Start norepinephrine drip.
D. Start phenylephrine drip.

14. An 81-year-old man with a history of Alzheimer's dementia and congestive heart failure presents from his nursing home after a witnessed aspiration event with cough and dyspnea. In the ED, he appears dehydrated and is hypoxic, requiring 4L NC, tachycardic to the 120s and hypotensive to 68/40 mmHg. His EKG is nonischemic, his CXR shows no acute process, and his labs show no anemia but an elevation in his creatinine. You decide to perform a BLUE protocol and the finding is shown in Figure 4.16.

What is the best next step in management?

A. Perform a thoracentesis.
B. Start antibiotics and fluid resuscitation.
C. Initiate diuresis.
D. Perform a thoracostomy.

15. A 74-year-old female with no significant medical history presents to the ED lethargic and profoundly

Systole Diastole

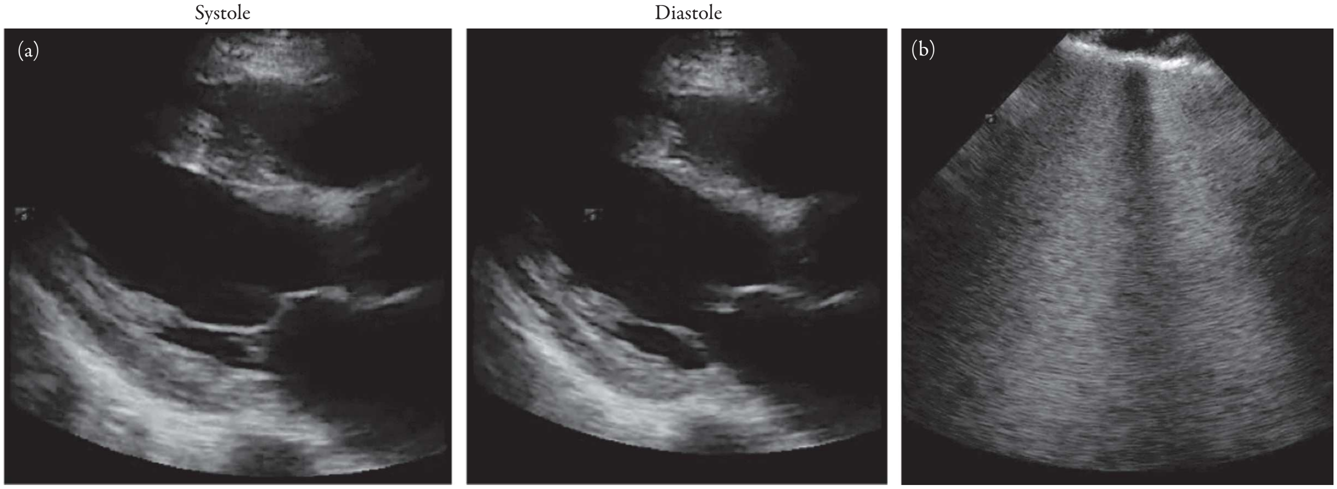

Figure 4.15

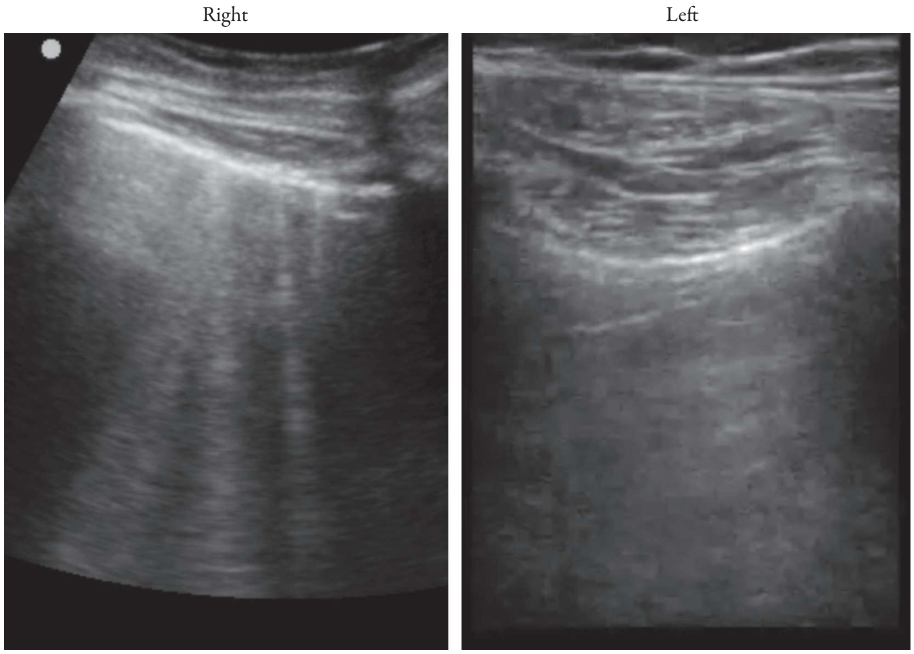

Figure 4.16

hypotensive. On exam, the patient is febrile and has dry mucous membranes and dark urine. Labs are notable for leukocytosis with left shift, and urinalysis is positive for leukocyte esterase and bacteria. She is started on broad-spectrum antibiotics and aggressive IV fluids. After a 30 ml/kg fluid bolus, the patient still remains hypotensive. You perform your serial exam using POCUS and obtain the images of her IVC shown in Figure 4.17a and Video 4.17 and carotid Doppler waveforms shown in Figure 4.17b.

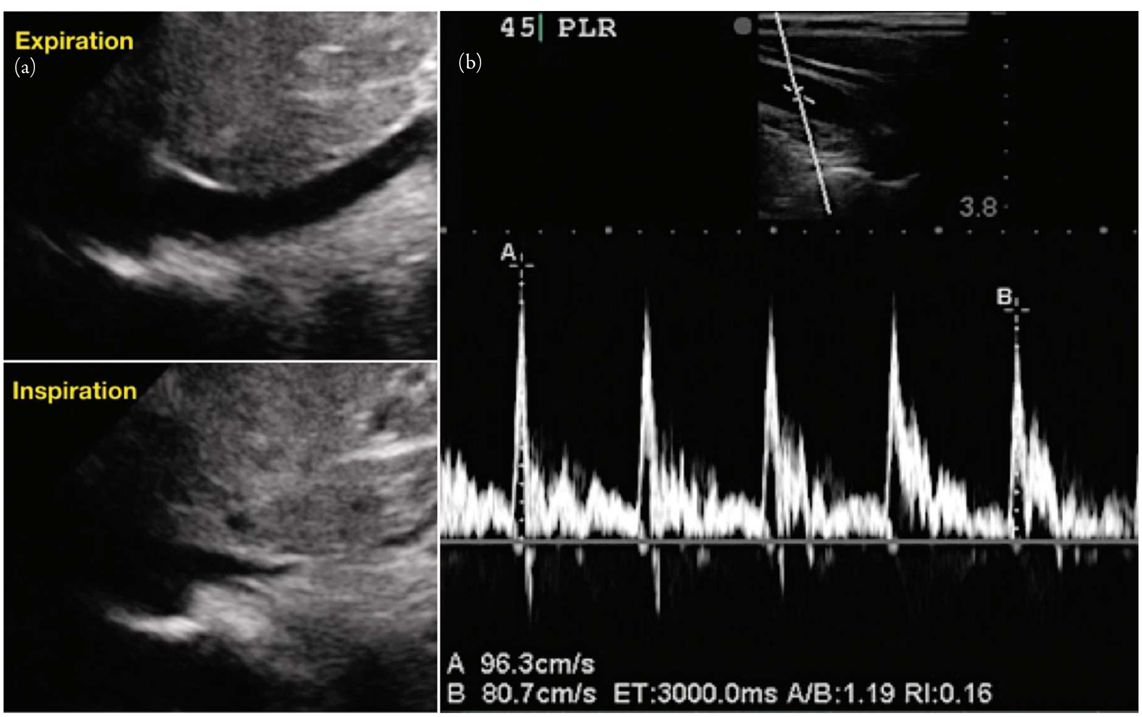

Figure 4.17

What is the next best step in management?

A. Continue fluid resuscitation with reassessment of fluid responsiveness (FR).
B. Send the patient for an emergent chest CT angiogram.
C. Start diuresis with IV furosemide.
D. Perform cardiac catheterization.

16. A 67-year-old man with hypertension and diabetes presents with several days of worsening lethargy, vomiting accompanied by fevers, and unilateral flank pain. In the ED, he is febrile to 40°C, hypotensive to 60/40 mmHg in sinus tachycardia at 120 beats per minute, and tachypneic to 24 breaths per minute. Labs are notable for leukocytosis and thrombocytosis with normal renal indices, lactate elevation, and a urinalysis showing large amounts of blood, white blood cells in clumps, and positive leukocyte esterase. He is given broad-spectrum antibiotics for presumed sepsis, and 3 liters of crystalloids (based on 30 mL per Kg weight) are given. On repeat vitals an hour later, he remains hypotensive to 80/50 mmHg and remains in normal sinus rhythm at 90 beats per minute but with labored breathing. A decision is made to sedate, paralyze and intubate the patient. An additional 1 liter of crystalloid is given during and after the intubation. Subsequent care is assumed in the ICU for septic shock from urinary source.

Before deciding on administration of additional IV fluids for hypotension, a bedside echocardiography is performed (see Figure 4.18).

Based on the available information, you conclude that:

A. The clinician should *not* give more fluids based on maximal IVC diameter.
B. The clinician should give more fluids based on the IVC variation.
C. The clinician should give more fluids based on the respiratory variations in peak aortic flow.
D. Both B and C are correct.

17. A 71-year-old male with a history of insulin-dependent diabetes mellitus and chronic kidney disease (baseline Cr 1.9 mg/dL) was admitted for septic shock in the setting of a purulent foot ulcer. On arrival to the ICU, the patient was started on norepinephrine for hypotension despite 3 liters of crystalloid resuscitation. The patient's nurse informs you that there has been no urine output since admission. You perform a POCUS exam (see Figure 4.19).

What is the best next step for management?

A. Administer another liter of normal saline bolus.
B. Place Foley catheter.
C. Administer an IV diuretic.
D. Repeat basic metabolic panel including creatinine and electrolytes.

18. A 45-year-old man is admitted to the medical ICU with pneumonia complicated by acute respiratory distress syndrome (ARDS). He has been intubated and mechanically ventilated for 15 days, with mild improvement of his overall condition. As he is weaned off paralysis, he becomes more uncomfortable, tachypneic to 40 breaths/minute with decreased oxygen saturation at 85%. Auscultation reveals decreased breath sounds bilaterally. Analyzing his ventilator waveforms, the treating physician notices reduced tidal volumes, high plateau pressures, and flow-time waveforms (Figure 4.20a). The physician suspects development of a tension pneumothorax. A quick bedside ultrasound shows Figure 4.20b.

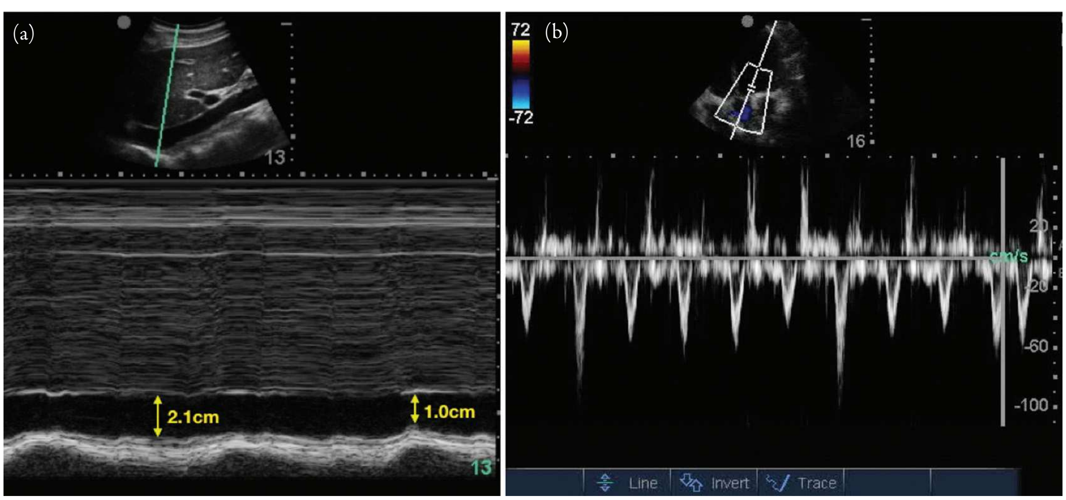

Figure 4.18

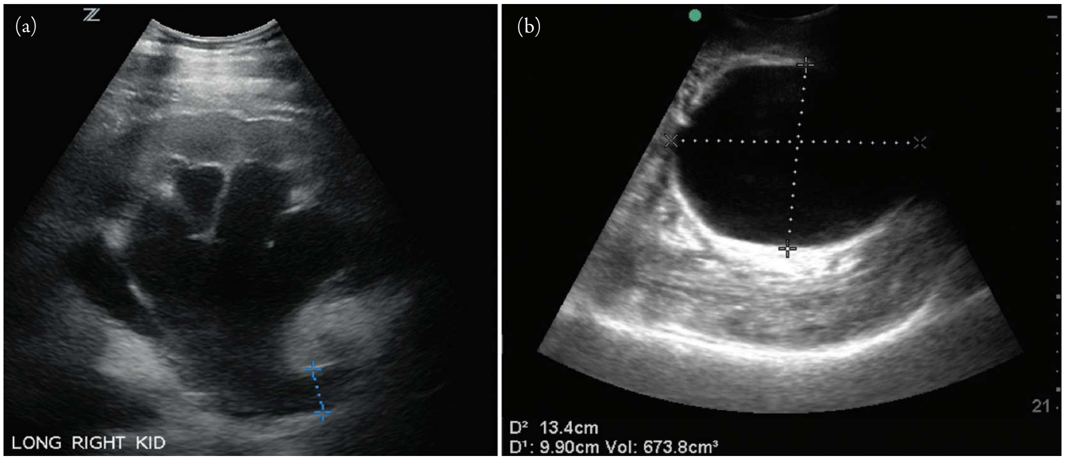

Figure 4.19

What is the next best step in management?

A. Prone positioning.
B. Sedate the patient and start neuromuscular blockade.
C. Obtain CT chest.
D. Place chest tube.

19. A 52-year-old man with a history of hyperlipidemia and alcoholism complicated by end-stage liver disease presented with large volume hematemesis in the setting of decompensated cirrhosis. He is intubated and status post-banding of esophageal varices via upper endoscopy. His ICU course is complicated by hemorrhagic shock requiring massive transfusion protocol, ARDS requiring significant sedation for lung protective ventilation, and acute renal failure requiring continuous renal replacement therapy. On hospital day 8, he is noted to be unresponsive despite being off of sedation. The exam is notable for small, minimally reactive pupils and a weak

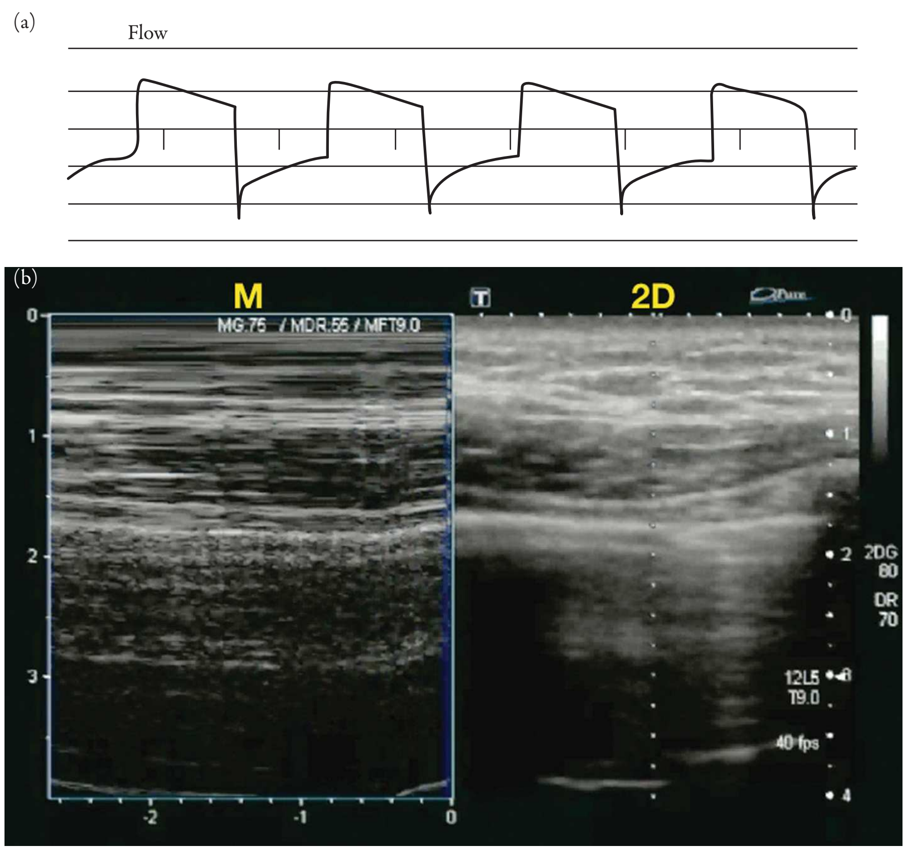

Figure 4.20

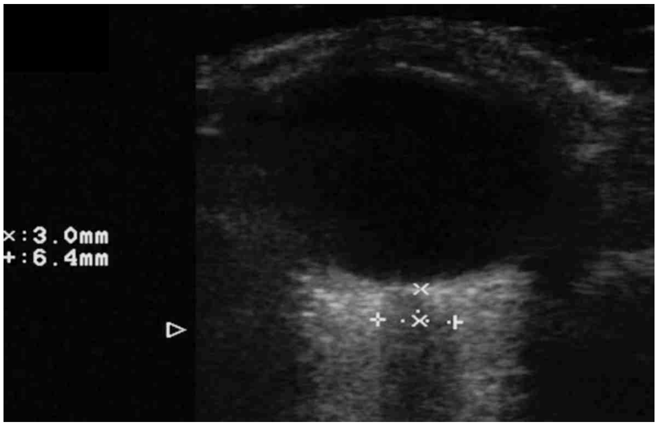

Figure 4.21

gag. A CT of the head is ordered; however, his bedside nurse is concerned that he is too unstable for transport. You perform an optic nerve sheath diameter assessment (Figure 4.21).

What is the next best step in management?

A. Place orogastric tube and administer lactulose.
B. Brain MRI with and without contrast when stable.
C. Elevate head of bed 30°, begin hyperventilation, administer IV mannitol and call neurosurgical consultation.
D. Initiate extended video electroencephalogram (EEG).

20. A 41-year-old male with a history of alcoholic cirrhosis had a prolonged hospital course complicated by hepatic encephalopathy, episodes of supraventricular tachycardia requiring amiodarone, and hepatorenal syndrome requiring hemodialysis. Pre-transplant LV ejection fraction was 75% without evidence of pulmonary hypertension. He is now 3 days status post-orthotopic liver transplant, found to have worsening hypoxia and increasing pressor requirements. CXR is notable for diffuse bilateral infiltrates. The patient is intubated, cultures are sent, and empiric antibiotics are started. His CXR and EKG are shown in Figure 4.22. You obtain an apical four chamber view on POCUS (Figure 4.23, Video 4.18).

What is the next best step in management?

A. Fluid resuscitation
B. Add phenylephrine as next pressor
C. Lung protective ventilation with inhaled nitric oxide
D. Inotrope with consideration of intra-aortic balloon pump

21. A 22-year-old male presents with dyspnea, cough, fevers, and fatigue for the past week. His vital signs are notable for temperature 38.9°C, blood pressure 135/83, heart rate 123, respiratory rate 20, O_2 96%. He looks fatigued. He has no jugular vein distention, and his heart sounds are regular but tachycardic. His lung sounds have some mild wheezing and crackles bilaterally. He has no edema. Considering that he has a viral syndrome, you give him an antipyretic and IV fluids. An EKG shows normal voltage and no evidence of arrhythmia or ischemia. A CXR shows no evidence of cardiomegaly and no acute pulmonary process. After 2 liters of normal saline, you decide to perform an echocardiography (see Figure 4.24 and Video 4.19).

What is your diagnosis?

A. The patient has RV strain
B. The patient has a pericardial effusion
C. The patient has a pneumonia
D. The patient likely has myocarditis

22. Your 89-year-old female patient is improving after her initial admission to the ICU for respiratory failure due to pneumonia. She is alert and normotensive and signals her desire to be removed from the ventilator. On her spontaneous breathing trial, you perform the thoracic ultrasound shown in Figure 4.25.

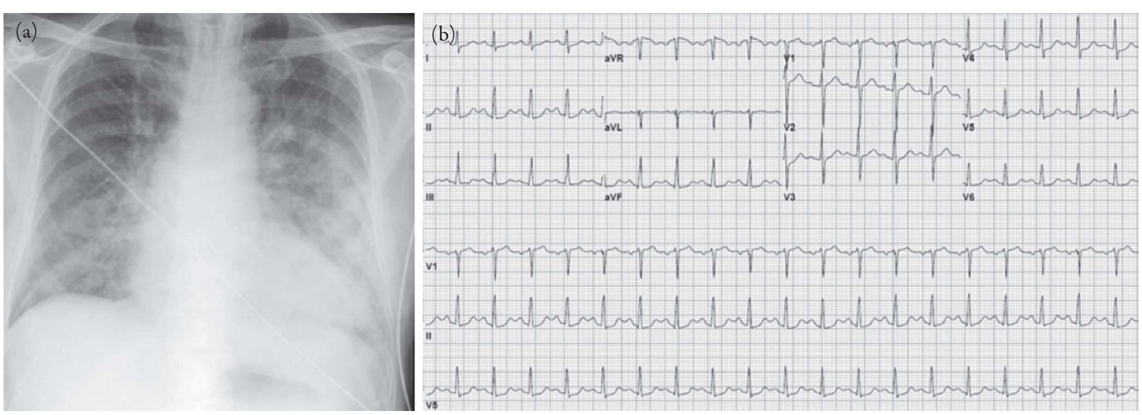

Figure 4.22

Systole Diastole

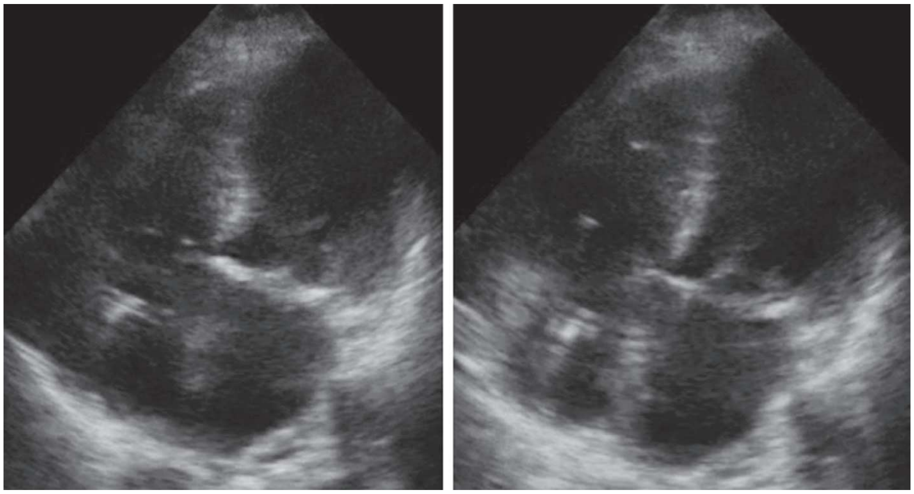

Figure 4.23

End systole End diastole

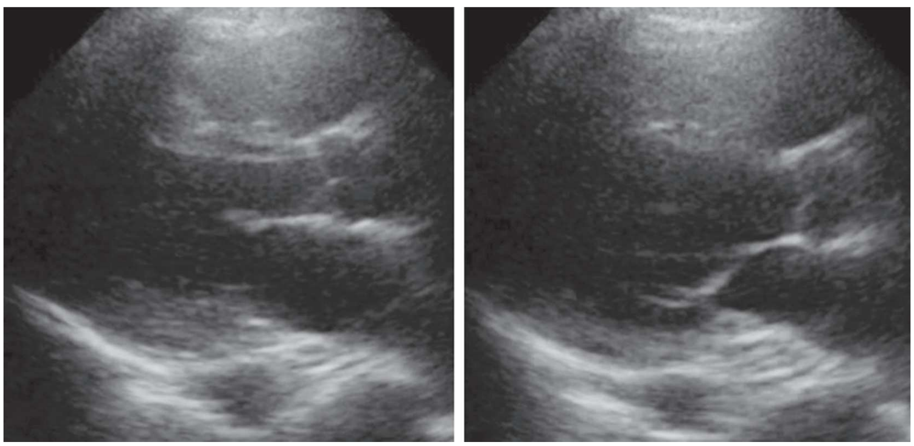

Figure 4.24

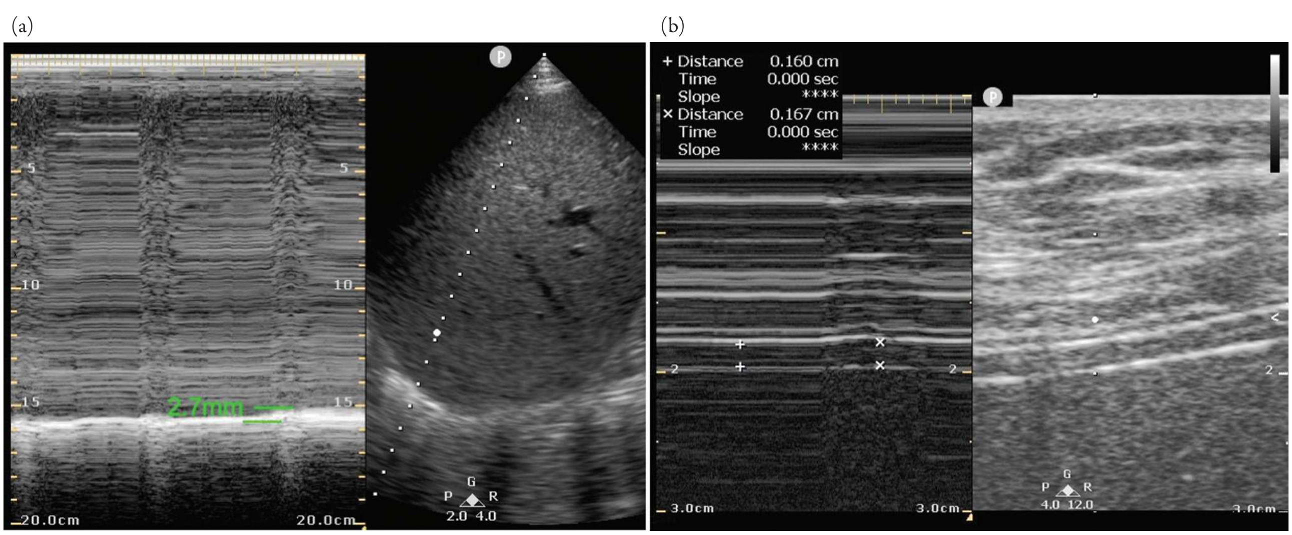

Figure 4.25

Figure 4.26

What is your assessment?

A. The patient has a consolidation
B. The patient has pulmonary edema
C. The patient is likely to be successfully extubated
D. The patient is likely to fail her weaning trial

23. A 65-year-old male presents with acute shortness of breath and altered mental status over the past 1 day. His heart rate is 106, blood pressure 190/110, SpO_2 92% on room air, temperature 97.6°, and respiratory rate 33. His EKG shows sinus tachycardia with no significant ST changes. He develops respiratory distress and is intubated. His post-intubation CXR is shown in Figure 4.26. An arterial blood gas is obtained and shows a PaO_2 of 80 on an FiO_2 of 90%. You obtain the bedside ultrasound images shown in Figures 4.27 and 4.28 and Video 4.20. What is the most likely cause of his shortness of breath?

A. Massive pulmonary embolism
B. COPD exacerbation
C. ARDS
D. Cardiogenic pulmonary edema

24. A 56-year-old female presents with abdominal pain and vomiting. Her heart rate is 118, blood pressure 95/40, SpO_2 96% on room air, temperature 102.4°, and respiratory rate 29. Urine dip shows large nitrite and positive leukocytes. Serum labs are ordered and pending. One liter of lactated ringers is given to the patient with resulting blood pressure of 97/44. A bedside ultrasound is performed before and after a passive leg raise (PLR) (Figure 4.29). What is the next best step in management?

A. Administer additional IV fluid.
B. Start norepinephrine.
C. Start vasopressin.
D. Administer furosemide.

25. A 72-year-old male is brought in by paramedics after being found pulseless at his living facility. The patient was intubated prior to hospital arrival and active chest compressions are being performed as he arrives to the ED. A TEE transducer is quickly inserted showing the image in Figure 4.30 with the area of maximal compression in the area shown by the arrow. What is the next best step in management?

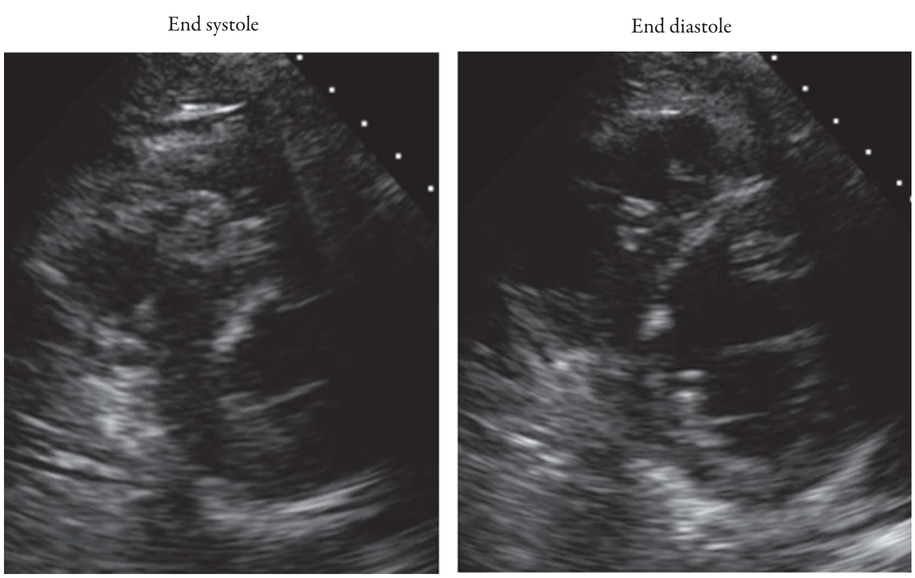

Figure 4.27

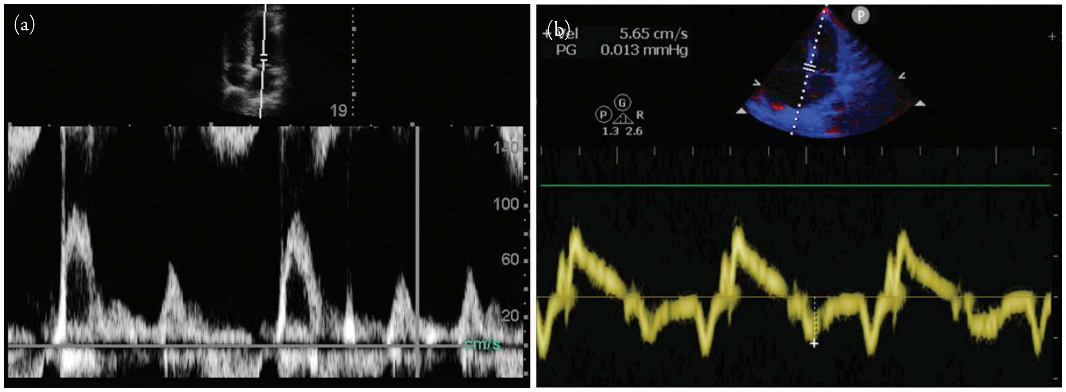

Figure 4.28

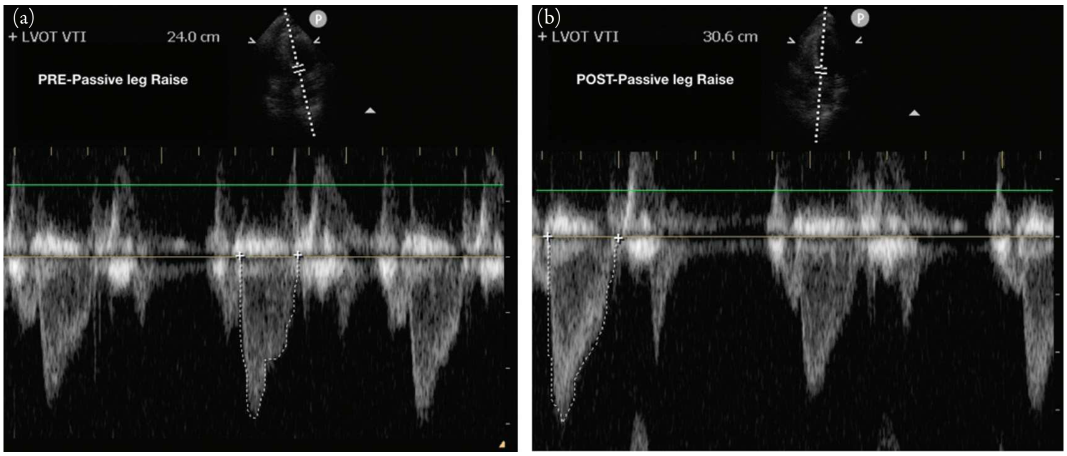

Figure 4.29

A. Stop chest compressions
B. No change
C. Perform compressions more caudally
D. Deeper chest compressions

26. An 88-year-old female is brought in by ambulance following a PEA arrest. The monitor shows asystole. They report CPR has been ongoing for 15 minutes. POCUS shows no change in appearance through the cardiac cycle (Figure 4.31, Video 4.21). Based on the ultrasound, what statement below is most correct?

A. The patient has a low likelihood of ROSC
B. The patient has no chance of ROSC
C. The patient should be defibrillated
D. The patient has achieved ROSC

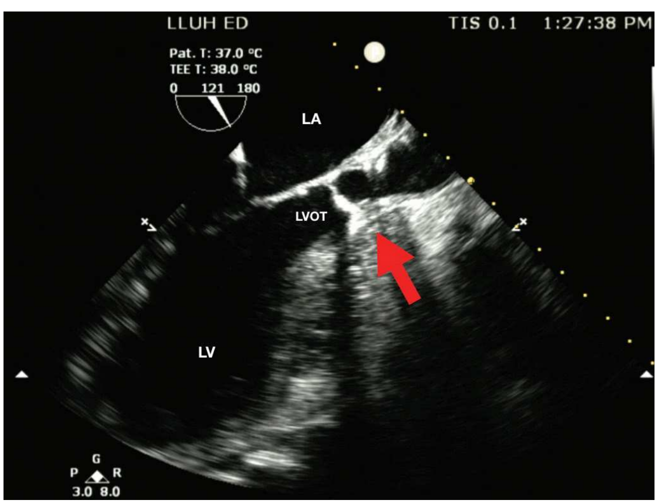

Figure 4.30

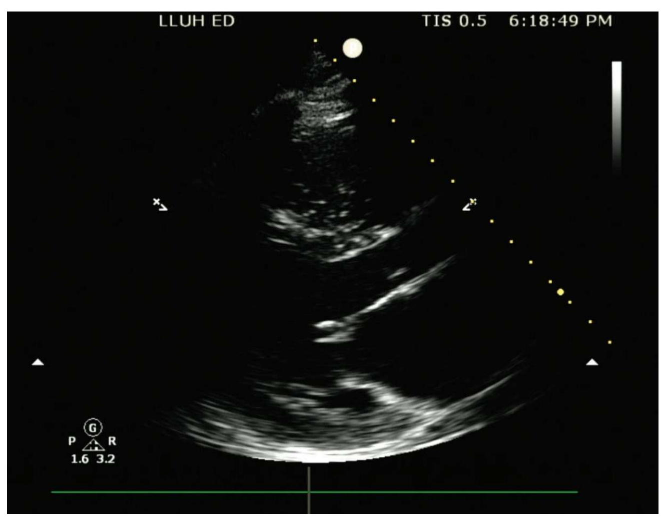

Figure 4.31

ANSWERS

1. EXPLANATION

A. Administer alteplase bolus of 50 mg over 2 minutes. Despite advances and updates to standardization of cardiac arrest management, outcomes from patients who suffer cardiac arrest remain poor. In addition to maintenance of effective circulation, advanced cardiac life support has focused on early identification of shockable rhythms and reversible causes of cardiac arrests.

This case is an illustration of thromboembolism (i.e., a pulmonary embolus) as cause of a PEA arrest. Figure 4.1a shows a short axis view with a grossly enlarged right ventricle in proportion to the left ventricle, suggestive of right-sided overload. There is a wide differential diagnosis depending on whether it is secondary to an acute or chronic process. However, in an acute setting, pulmonary embolism should be considered. While rarely one may find a clot in transit, additional clues may be obtained from quick peripheral vascular imaging. Figure 4.1b shows a noncompressible vein in the femoral vein suggestive of a DVT. Indeed, Prandoni et al., in a recent cross-sectional study, highlights pulmonary embolism as an often forgotten cause of syncope, and this patient's initial presenting symptom of syncope may have been a sentinel event for a pulmonary embolus. As such, a massive pulmonary embolism is suspected as the potential cause of this patient's PEA arrest, for which administration of alteplase is indicated.

There is no current indication for an airway inspection based on the given clinical information (choice B is incorrect). While it is important to rule out an infection and reasonable to start empiric antibiotics, infection does not appear to be the likely cause of the arrest given the acute onset and POCUS findings (choice C is incorrect). Choice D is incorrect as there does not appear to be a significant pericardial effusion to cause hemodynamic collapse.

Learning Objective: In a patient with pulseless electrical activity (PEA) arrest, signs of right ventricular (RV) dysfunction on echo and/or positive deep vein thrombosis (DVT) ultrasound should prompt clinicians to treat for massive pulmonary embolism.

FURTHER READING

Breitkreutz R, Walcher F, Seeger FH. Focused echocardiographic evaluation in resuscitation management concept of an advanced life support-conformed algorithm. *Crit Care Med*. 2007;35(5 Suppl):S150–S161.

Comess KA, DeRook FA, Russell ML, et al. The incidence of pulmonary embolism in unexplained sudden cardiac arrest with pulseless electrical activity. *Am J Med*. 2000 Oct 1;109(5):351–356.

Neumar RW, Shuster M, Callaway CW, et al. Part 1: Executive Summary: 2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation*. 2015;132:S315.

Prandoni P, Lensing AWA, Prins MH, et al. Prevalence of pulmonary embolism among patients hospitalized for syncope. *N Engl J Med*. 2016;375:1524–1531.

2. EXPLANATION

A. Continue CPR and prepare for unsynchronized defibrillation. Despite the presence of what appeared to be asystole in this obese patient on telemetry, your POCUS echo showed evidence of fine v-fib. Management of fine v-fib involves delivering an electrical shock. Without ultrasound, the telemetry is interpreted as asystole, which has a different resuscitation pathway (choice B is incorrect).

POCUS in cardiac arrest allows the physician to guide resuscitation with a better understanding of physiological process behind the cardiac arrest. It can be used in the assessment of the *presence or absence of cardiac output* (presence of pulse) and as an alternate *framework to the etiology* of "shockable" or "nonshockable" cardiac arrests.

Bag valve mask ventilation should be initiated immediately, along with chest compressions if multiple providers are present. Immediate ET intubation can cause delay in ventilation and oxygenation and should be avoided unless it can be performed without interruption of chest compressions or adequate ventilation cannot be successfully performed by noninvasive measures (choice C is incorrect). While chemical cardioversion with agents such as amiodarone and/or lidocaine may be considered, the American Heart Association ACLS guideline recommend early unsynchronized defibrillation in a pulseless v-fib as the initial step in management (choice D is incorrect).

FURTHER READING

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Neumar RW, Shuster M, Callaway CW, et al. Part 1: Executive Summary: 2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation*. 2015;132:S315.

Learning Objective: Fine ventricular fibrillation (v-fib) may appear as asystole on the electrocardiogram (EKG). Perform a POCUS echocardiography, as this would change the advanced cardiovascular life support (ACLS) management from PEA arrest to v-fib management.

3. EXPLANATION

D. Veno-arterial ECMO. Post-catheterization cardiac arrest could be due to a number of complications that require immediate diagnosis and management. On POCUS echo, there is markedly reduced LV ejection fraction with preserved RV function, suggestive of acute ischemic cardiomyopathy likely due to the dissection of a coronary artery during the procedure. The patient will require mechanical support, especially in refractory cardiac arrest where patients receiving ECMO have survival rates up to 40%. Once stabilized, he will likely require surgery. In the setting of nonobstructive coronary artery disease, it would be reasonable to assume a nonischemic etiology, especially in the setting of advanced lung disease. In this case, bedside ultrasound findings can effectively rule out acute RV failure as the cause for his arrest (choices A and B are incorrect). Periprocedural oversedation can result in cardiac arrest depending on the timing but would not be associated with reduced ejection fraction (choice C is incorrect).

FURTHER READING

Napp LC, Kuhn C, Bauersachs J. ECMO in cardiac arrest and cardiogenic shock. *Herz*. 2017;42(1):27–44.

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Prakash R, Starovoytov A, Heydari M, et al. Catheter-induced iatrogenic coronary artery dissection in patients with spontaneous coronary artery dissection. *JACC: Cardiovasc Interv*. 2016;9(17):1851–1853.

Learning Objective: Recognize post-catheterization cardiac arrest with the need for extracorporeal membrane oxygenation (ECMO) support.

4. EXPLANATION

B. Initiate rapid blood transfusion. The patient has a spontaneous splenic rupture, and the key component to this scenario is the presence of a free fluid (presumably blood) in the abdominal cavity on the bedside ultrasound. A massive blood transfusion protocol should be initiated. After the initial stabilization of the patient with aggressive transfusions, the emergent surgical consult for an immediate exploratory laparotomy is prudent at this point. (Of note, most patients with HbSS who reach adulthood have autoinfarcted their speens while some young adults may have still have functional spleens.)

As noted in the question stem, the patient has hardly used his PCA and the progressive altered mental status is not related to his use of PCA but likely related to acute intra-abdominal blood loss (choice A is incorrect).

Obtaining a CT abdomen in this unstable patient is not advised as the patient is hemodynamically unstable (choice C is incorrect). Similarly, if adequate IV access is available, placement of a central venous catheter would not be warranted at this time. Placement of two large bore IVs (18 gauge or larger) would be much more useful in infusing blood products rapidly when compared to conventional triple lumen catheters (choice D is incorrect).

FURTHER READING

Rees DC, Williams TN, Gladwin MT. Sickle-cell disease. *Lancet*. 2010;376:2018.

Shoemaker MT, Pitney AC, Harford DJ, Barker JA. Acute splenic rupture in an adult with homozygous sickle cell anemia treated with chronic transfusions. *J Pediatr Hematol Oncol*. 2004 Dec;26(12):849-–851.

Sommer N, Schnüriger B, Candinas D, Haltmeier T. Massive transfusion protocols in non-trauma patients: a systematic review and meta-analysis. *J Trauma Acute Care Surg*. 2018 Oct. doi:10.1097/TA.0000000000002101.

Learning Objective: POCUS can rapidly differentiate and identify nontraumatic hemorrhagic shock from other forms of shock in the patient with PEA arrest.

5. EXPLANATION

B. Esophageal rupture. This case describes a patient with a new large pleural effusion, which was not present on chest imaging only several hours prior to this event. The patient most likely had an esophageal rupture related to vomiting and the additional effect of positive pressure ventilation. Fluid seen on the ultrasound in the pleural space shows a dense, particle-rich free-floating fluid, which can be described as a "plankton sign." In the setting of trauma, a hemothorax or ruptured aortic dissection can present in a similar fashion. Along with further attempts to stabilize the patient, immediate chest tube placement and emergent surgical consultation are necessary at this time.

Spontaneous pneumothorax would show a lack of lung sliding on ultrasound (choice A is incorrect). Aspiration pneumonitis and/or pneumonia is suspected given his history and CXR findings; nevertheless, his sudden profound decline implies an additional event, such as

esophageal perforation. Pleural malignancy may show consolidation or pleural thickening on ultrasound as well as the plankton sign, but the acute interval development of a malignant pleural effusion is unlikely (choices C and D are incorrect).

FURTHER READING

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Chichra A, Makaryus M, Chaudhri P, Narasimhan M. Ultrasound for the pulmonary consultant. *Clin Med Insights Circ Respir Pulm Med*. 2016;10:1–9.

Lichtenstein D. Noninvasive recognition of the nature of a fluid pleural effusion. In: *Lung Ultrasound in the Critically Ill: The BLUE Protocol*. Cham, Switzerland: Springer; 2015:320–321.

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Learning Objective: Recognize the splenorenal view of a large pleural effusion and Plankton's sign in a patient with a ruptured esophagus.

6. EXPLANATION

C. Administer IV volume repletion and inotropic support while awaiting pericardiocentesis. The key feature of the bedside ultrasound is the presence of pericardial effusion, which can be seen in this apical four-chamber view showing circumferential fluid in the pericardial space. While large volume effusions may be readily visible in most views, careful examination may be needed for smaller and/or loculated fluid, which can still cause tamponade physiology if the accumulation is rapid. Collapse of the RV in early diastole, as well as RA systolic collapse and inversion, are suggestive of a tamponade physiology on echocardiogram. Deploying M-mode with the axis through anterior leaflet of the mitral valve and the RV free wall, one can find the RV free wall moving paradoxically inwards as the mitral valve opens (see Figure 2.46). These echocardiographic findings are due to increased intrapericardial pressure precluding the cardiac chamber filling. Additional findings on ultrasound may include the inferior vena cava (IVC) dilation with a loss of respiratory variation. Lastly, Doppler can be used to detect exaggerated respiratory variation in blood flow across the valve (i.e., the mitral or tricuspid), where there is greater than 25% inflow of blood during the beginning of inspiration as compared to expiration (see Figure 2.38).

Table 4.1. **SUMMARY OF ECHOCARDIOGRAPHIC FINDINGS IN CARDIAC TAMPONADE**

2D and M-Mode	
RV collapse during early diastole	**Occurs when intracavitary cardiac pressure transiently fall below intrapericardial pressure in early diastole causing compression of the RV outflow tract (compressible area of the RV)**
RA collapse/inversion	**Occurs immediately after normal atrial systolic contraction; the RA wall remains collapsed throughout atrial diastole when RA filling is expected to occur**
IVC dilation and loss of respiratory variation	**Suggestive of increased RA pressure as seen in cardiac tamponade**
Doppler	
Exaggerated inflow velocity variation during respiration	**Measurement of phasic variation in intrathoracic pressure, with increase in tricuspid flow during inspiration and decrease during expiration; difference greater than 25% suggests presence of ventricular interdependence (i.e., pulsus paradoxus)**

Note. RV = right ventricular; RA = right atrial; IVC = inferior vena cava; RA = right atrial.

Given these findings, the best management for acute cardiac tamponade is administering IV fluids and inotropic support while awaiting pericardiocentesis. Despite obvious fluid overload and acute on chronic kidney failure, patient is reliant on venous return and the reduction of preload by fluid removal may be detrimental (choices A and D are incorrect). Small and collapsible RV with a large pericardial effusion is not indicative of venous thromboembolism (choice B is incorrect).

See Table 4.1.

FURTHER READING

Armstrong WF, Ryan T. Pericardial disease. In: Feigenbaum H, Armstrong W, Ryan T, eds. *Feigenbaum's Echocardiography*. 7th ed. Philadelphia, PA: Lippincott Williams & Wilkins:248–253.

Chandraratna PA, Mohar DS, Sidarous PF. Role of echocardiography in the treatment of cardiac tamponade. *Echocardiography*. 2014;31(7):899–910.

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Learning Objective: Successfully recognize a large pericardial effusion with features of cardiac tamponade based on right atrial (RA) systolic collapse and inversion of the RV free wall.

7. EXPLANATION

D. Acute coronary syndrome. The patient had a pre-op echo with normal systolic function. Comparatively, Figure 4.6 and Video 4.10 show an acute drop in LV ejection fracture (EF) with septal regional wall motion abnormality. Based on the patient's acute presentation and risk factors (diabetes and hyperlipidemia), a likely etiology of his hypotension is an acute drop in EF secondary to possible acute coronary syndrome.

In the case of immediate post-op hemorrhagic shock or early sepsis, a bedside echo would show a normal or hyperdynamic heart (choices A and B are incorrect), or, if abnormal LV dysfunction is seen, there is typically a global pattern of ventricular dysfunction. Pulmonary embolism would possibly lead to a large RV with reduced function, but it would not lead to the LV seen in this patient (choice C is incorrect).

FURTHER READING

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Landesberg G, Beattie S, Mosseri M, et al. Perioperative myocardial infarction. *Circulation*. 2009;119:2936–2944.

Vincent JL, De Backer D. Circulatory shock. *N Engl J Med*. 2013;369:1726.

Learning Objective: Patients with new global or regional LV systolic dysfunction should be evaluated for acute coronary syndrome.

8. EXPLANATION

B. Start IV unfractionated heparin while awaiting STAT CT chest angiography. Here, the ultrasound image shows RV dysfunction with akinesis of the mid free wall and increased contractility of the apical wall, known as a McConnell's sign. It is a highly distinct sign of acute pulmonary embolism, though it is not specific for pulmonary embolism, seen in only about one-third of cases. McConnell's sign is more commonly associated with RV infarction. Supporting images can include a dilated right ventricle and the D-shaped LV, which suggest high RV pressure and RV overload due to an acute massive pulmonary embolism. Additional information such as presence of a lower extremity venous thrombus which can also be quickly evaluated with bedside vascular imaging may support the diagnosis of massive pulmonary embolism. Thus, anticoagulation should be initiated while awaiting chest imaging.

The ultrasound images in this case do not support cardiac tamponade, myocardial infarction, or an acute abdominal pathology as the likely cause of this patient's hemodynamic instability (choices A, C, and D are incorrect).

FURTHER READING

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Learning Objective: Recognize RV dilation and McConnell's sign in a patient with pulmonary embolism.

9. EXPLANATION

C. DVT. Hypoxia, tachycardia, and acute dyspnea in the setting of active malignancy and normal CXR would raise clinical suspicion for pulmonary embolism. Unfortunately, this patient's chronic kidney disease precludes the use of a CT pulmonary angiogram to make a definitive diagnosis. Surely, the patient could undergo a more definitive ventilation-perfusion scan to delineate the pulmonary embolism; however, a lower extremity ultrasound showing DVT would be a faster and a cost-effective diagnostic tool. Also, the patient can be started on anticoagulation more quickly instead of waiting for a confirmatory ventilation-perfusion scan, which has limitations in certain patient populations such as pre-existing lung disease.

Choice A shows large pleural effusion, choice B shows large pneumothorax, and choice D shows evidence of low EF. None of these fit the patient's clinical picture.

FURTHER READING

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Kearon C. Natural history of venous thromboembolism. *Circulation*. 2003;107:I22.

Learning Objective: Consider venous thromboembolic disease in patients with risk factors, acute dyspnea, and normal CXR.

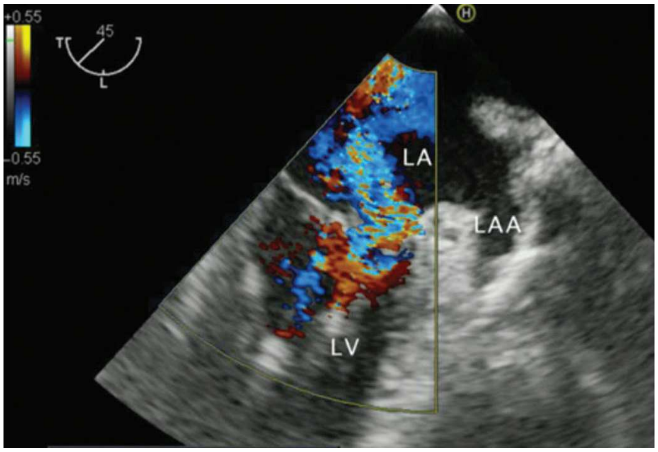

Figure 4.32 Mid-esophageal 2-chamber view using transesophageal echocardiography. Severe mitral regurgitation and eccentric regurgitant jet blowing rightward within the left atrium is seen. LA = left atrium; LV = left ventricle; LAA = left atrial appendage. From Figure 1C of Kashiura M, Tateishi K, Yokoyama T, et al. Unilateral cardiogenic pulmonary edema associated with acute mitral regurgitation. *Acute Med Surg*. 2017;4(1):119–122. doi:10.1002/ams2.234.

10. EXPLANATION

C. Consult cardiothoracic surgery consultation for possible mitral valve repair/replacement. While classically pulmonary edema is associated with bilateral peribronchial cuffing and/or patchy shadowing with air bronchograms, unilateral pulmonary edema may rarely occur in approximately 2% of cases. Bedside echocardiography evidence of eccentric mitral regurgitant (MR) jet may be supportive of this diagnosis, especially in a tachycardic patient when flail leaflet suggesting MR is difficult to visualize, as in Figure 4.12. Notably, there is no evidence of LA enlargement, which is typically seen in chronic MR. Thus, in the presence of both eccentric MR jet, roughly normal left atrium size, and a CXR showing unilateral edema, one should consider a posterior mitral leaflet rupture in the differential diagnosis.

Acute mitral regurgitation due to papillary muscle rupture is a potential complication of recent ischemia, as evidenced by the patient's chest pain in the preceding days, which can lead to acute pulmonary edema. Surgical consultation is the treatment of choice. There is no need for initiation of hemodialysis or initiation at this point (choice B is incorrect) and treating the patient for pneumonia or COPD exacerbation would be inadequate (choices A and D are incorrect).

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Attias D, Mansencal N, Auvert B, et al. Prevalence, characteristics, and outcomes of patients presenting with cardiogenic unilateral pulmonary edema. *Circulation*. 2010;122(11):1109–1115.

Learning Objective: Recognize flail mitral valve/leaflet on limited cardiac ultrasound in a patient with acute pulmonary edema.

11. EXPLANATION

A. STAT TEE. Bedside echocardiography can provide invaluable information regarding various cardiovascular abnormalities. Specifically, acute valvular pathologies are often overlooked in the initial evaluation of unstable patients. While a TEE is more sensitive and specific for detection of aortic dissections compared to transthoracic echocardiograms (TTE), a TTE can quickly detect apparent complications including aortic insufficiency and hemopericardium.

The apical 5-chamber window obtained from bedside echocardiography in Figure 4.13 and Video 4.14 reveals aortic regurgitation. In a patient with suspected acute aortic insufficiency, ascending aortic dissection is in the differential, especially if the patient is unstable with hemodynamic collapse and symptoms of pulmonary edema. A STAT TEE is warranted to make the diagnosis in this patient with a rapid blood pressure change from clinic to ED (see Figure 4.33a and Video 4.22). Alternatively, a suprasternal notch view on TTE—if the window is adequate—can be used as well (Figure 4.33b and Video 4.23).

A CT angiography of the chest can quickly and accurately confirm this life-threatening condition but should be avoided in this hemodynamically unstable patient (choice B is incorrect). Left and right heart catheterizations are not indicated at this time (choices C and D are incorrect).

FURTHER READING

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Learning Objective: Patients presenting with severe chest pain and new evidence of aortic insufficiency or pericardial effusion should be evaluated for ascending aortic dissection. Often a transesophageal echocardiography (TEE) is indicated especially when the patient is unstable for CT angiography.

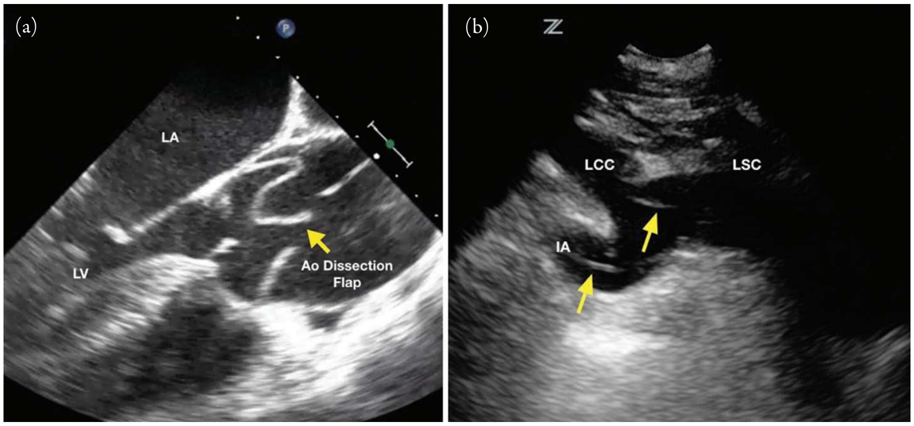

Figure 4.33 (a) Mid-esophageal long axis view using transesophageal echocardiography. Arrow points to ascending aorta dissection flap. LA = left atrium; LV = left ventricle. (b) Suprasternal view using transthoracic echocardiography. Arrows point to dissection flap going into the innominate artery and the left common carotid artery. IA = innominate artery; LCC = left common carotid artery; LSC = left subclavian artery.

12. EXPLANATION

A. Endotracheal intubation. ET intubations are often performed in emergent settings to ensure adequate ventilation and oxygenation as well control of the unstable airways in critically ill patients. Post-procedurally, correct placement must be confirmed as unrecognized esophageal intubations can have deleterious outcomes. Several tools are often utilized for confirmation of proper tube placement after an ET intubation with varying sensitivities and limitations. While quantitative capnography remains the most reliable method, it may not be readily available. The use of ultrasound for the confirmation of proper ET tube placements have gained popularity in the last several years and have been validated by several studies and meta-analyses. Specifically, the pooled sensitivities and specificities of TRUE (tracheal rapid ultrasound exam) for emergency intubations have been reported to be 98% and 94%, respectively. This case further illustrates the use of ultrasound to reliably detect tracheal placement of the tube. Figure 4.14 confirms the placement of the ET tube in the trachea, as the ET tube generally is masked by air artifact, or in some cases may display ring down artifact. Note the muscular but collapsed esophagus just to the right and deep to the trachea on this image. Delivering tidal volumes via bag valve mask ventilation while imaging the diaphragm for excursion can also help to confirm successful intubation.

In esophageal intubation, there is the presence of a "double lumen," "double tract," or "double trachea" sign, as the ET tube is inserted into the esophagus and therefore distends it (Figure 4.34). POCUS is not indicated for evaluation of tracheo-esophageal fistula (choice C is incorrect).

FURTHER READING

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Learning Objective: Confirm ET tube placement on transtracheal ultrasound in a patient requiring emergent intubation.

13. EXPLANATION

C. Start norepinephrine drip. The patient presents with presumed sepsis from a urinary tract infection. Based on clinical history alone, this represents septic shock, and the

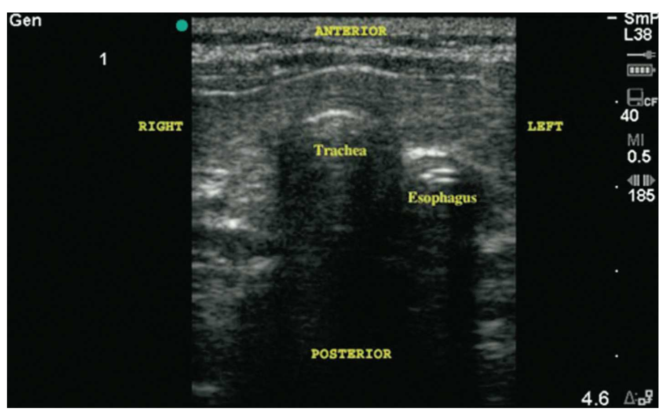

Figure 4.34 Esophageal intubation. From Figure 2 of Werner SL, Smith CE, Goldstein JR, Jones RA, Cydulka RK. Pilot study to evaluate the accuracy of ultrasonography in confirming endotracheal tube placement. *Ann Emerg Med*. 2007;49(1):75–80.

patient may benefit from more fluids (30 ml/kg based on surviving sepsis guidelines) prior to initiating pressor support. However, there is evidence of mixed septic and cardiogenic shock given increasing oxygen requirements after 2 liters of fluids, a POCUS echo showing a reduced ejection fraction, and dense B-lines suggestive of pulmonary edema. While this POCUS cannot assess fluid responsiveness (FR), it is likely that aggressive fluid resuscitation may lead to worsening pulmonary edema and overall clinical deterioration (choice A is incorrect). In a scenario like this, choosing norepinephrine, a pressor indicated as first line for septic and cardiogenic shock, would be more appropriate.

Patient's clinical scenario is inconsistent with the presence of clinically significant pulmonary embolism (choice B is incorrect). Norepinephrine is the recommended first-line vasopressor in septic shock and has a better impact on the inotropic effect via alpha and beta-1 adrenergic system, as compared to phenylephrine, which only has effect on the alpha adrenergic system, making it a more desirable agent for patients with reduced LV ejection fraction without significant tachy-arrhythmias (choice D is incorrect).

FURTHER READING

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ProCESS Investigators, Yealy DM, Kellum JA, et al. A randomized trial of protocol-based care for early septic shock. *N Engl J Med*. 2014;370:1683–1693.

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Learning Objective: Recognize a septic patient with volume overload after aggressive fluid resuscitation with presence of B-lines and poor systolic function.

14. EXPLANATION

B. Start antibiotics and fluid resuscitation. In Figure 4.15, there is unilateral B-lines on the right lung, which when coupled with the report of aspiration, is suggestive of pneumonia. It may also be due to inflammation from a pulmonary embolism, particularly if the B-line pattern is focal to a particular lung region. Bilateral presence of B-lines suggests pulmonary edema; in someone with a history of congestive heart failure, it is likely cardiogenic in etiology.

The Bedside Lung Ultrasound Evaluation protocol was one of the earliest ICU-based ultrasound protocols to evaluate patients with acute dyspnea. Briefly, the protocol is divided into three zones (see Figure 4.35):

Zone 1: Bilateral anterior lung zones to evaluate for pneumothorax

Zone 2: Bilateral inferior-lateral lung zones to evaluate for alveolar-interstitial syndrome

Zone 3: Bilateral posterior-lateral lung zones to evaluate for posterior-lateral alveolar and/or pleural syndrome (i.e., pneumonia and/or pleural effusion)

The FALLS protocol is an adaptation of the BLUE protocol with integration of basic cardiac windows to assess the etiology of circulatory failure or shock. It starts with assessing for etiologies of obstructive shock- cardiac tamponade, massive PE, and tension pneumothorax. If there is no evidence of obstructive shock, the next step is to assess for cardiogenic shock using both LV systolic assessment as well as presence of B-lines and plethoric IVC. If neither obstructive or cardiogenic shock are likely, then hypovolemic or distributive shock are more likely, and the FALLS protocol can then be used serially to assess fluid status after each fluid bolus (see Figure 4.36).

For POCUS clinicians who are familiar with other protocols for shock, such as the RUSH exam or the FATE exam, there is much overlap in terms of the individual components. While it is important to be familiar with each protocol, the clinician should be flexible and adopt only the needed components for the patient and his or her likely shock etiology.

FURTHER READING

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Learning Objective: Unilateral presence of B-lines in the right clinical setting suggests an infectious etiology to dyspnea, whereas a bilateral B-line pattern suggests pulmonary edema. POCUS assessment of B-lines has greater sensitivity and specificity than chest radiography.

15. EXPLANATION

A. Continue fluid resuscitation with reassessment of FR. The relationship between heart and lungs and the cyclic effect of breathing on preload variability, as well as dynamic parameters of preload responsiveness, are key concepts in the

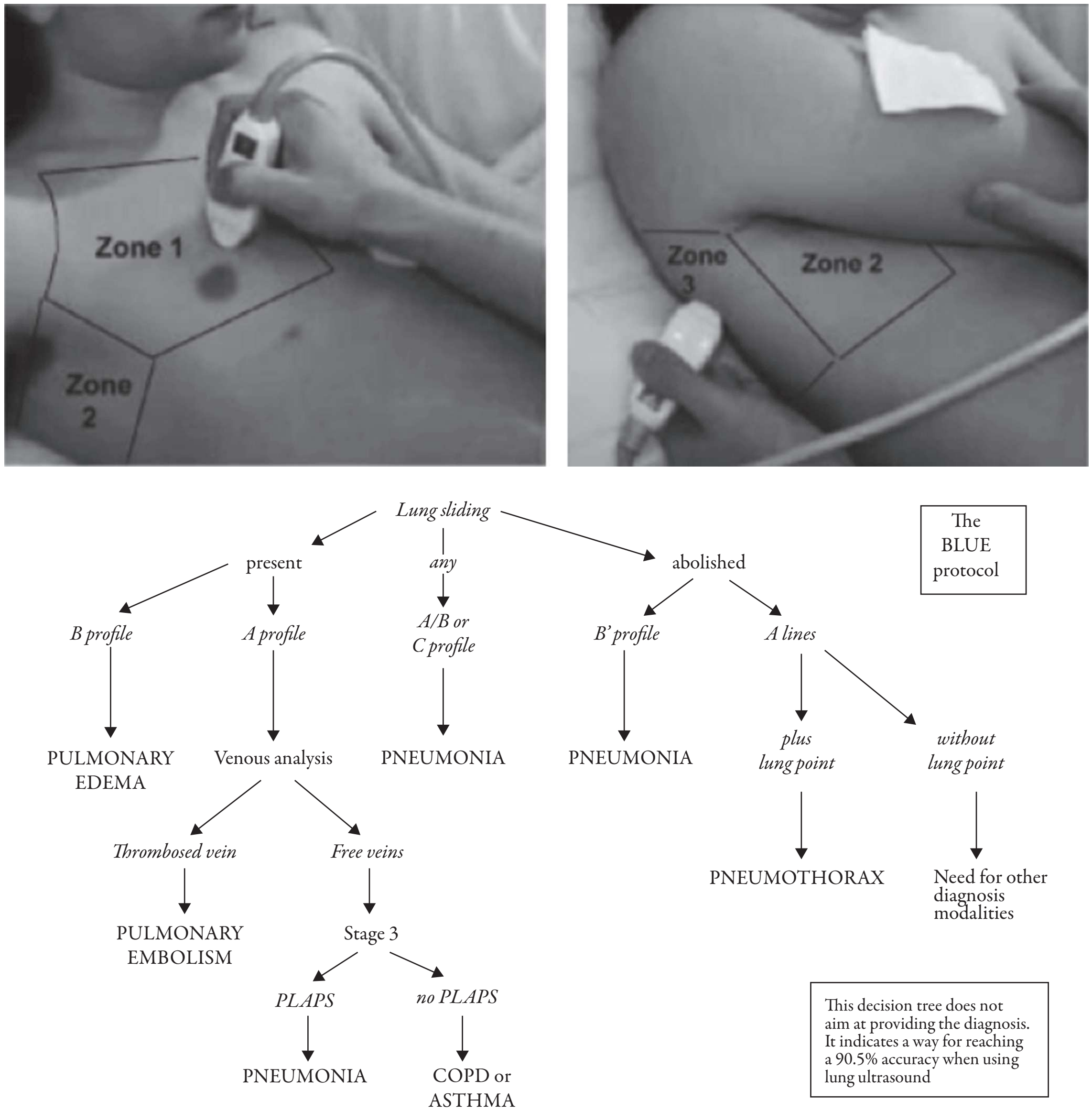

Figure 4.35 **Blue protocol.** PLAPS = posterior lateral alveolar pleural syndrome. From Figures 1 and 7 of Lichtenstein DA, Meziere G. Relevance of lung ultrasound in the diagnosis of acute respiratory failure: The BLUE Protocol. *Chest.* 2008;134(1):117–125.

management of septic shock. While various technologies able to capture respiratory variability in pulse pressure or stroke volume are well validated, 2D and Doppler ultrasound measures are reported to be useful in FR assessment as well.

Figure 4.17a and Video 4.17 show a collapsible IVC in this patient. The IVC diameter correlates with central venous pressures in both mechanically ventilated and spontaneously breathing patients. In contrast, IVC distensibility [(maximum diameter – minimum diameter)/minimum diameter] can be assessed only in patients on invasive mechanical ventilation with conventional tidal volumes that are in sinus rhythm. The applicability of IVC distensability in spontaneously breathing patient is less clear.

Carotid peak systolic velocity (PSV) during the respiratory cycle (i.e., pulse variation) is another method to assess FR in which the variability is defined as the difference between peak and minimum systolic velocity divided by the mean of its difference (Max PSV – Min PSV)/[(Max PSV + Min PSV)/2]. A prospective cohort study by Ibarra-Estrada et al. used a cut-off value of 14% or greater with a high positive predictive value for FR as defined as >15% of stroke volume increase. In Figure 4.17b, the calculated pulse variation is 17.6%, suggestive of significant pulse variation. Thus, fluid resuscitation with reassessment of FR should be performed.

Other measures obtained by bedside ultrasonographic assessment, such as peak aortic or radial velocities or carotid corrected flow time, have been described as possibly useful in shock resuscitation literature.

Choice B, which implies suspicion for pulmonary embolism; Choice C, which implies fluid overload; and Choice

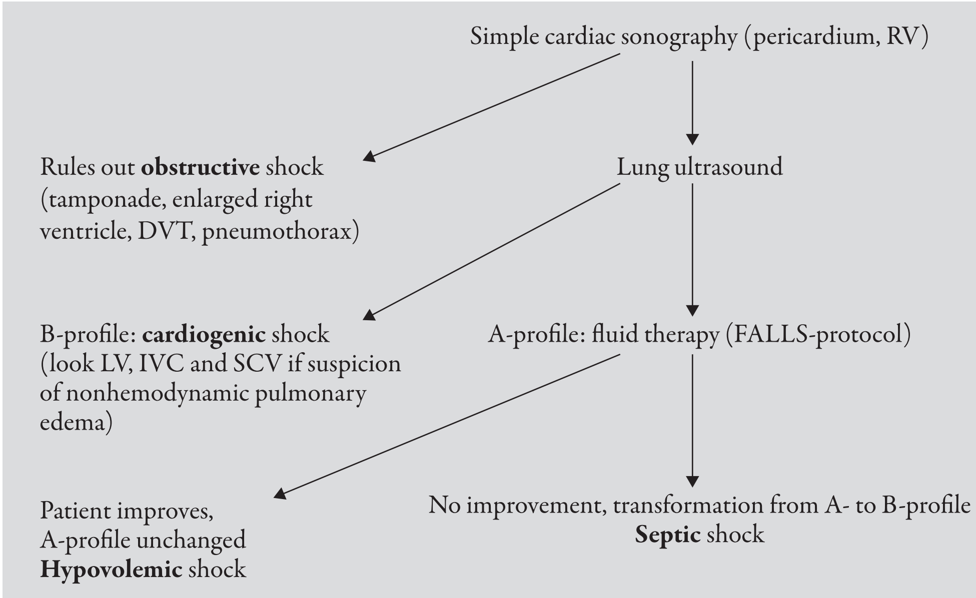

Figure 4.36 **Falls protocol.** DVT = deep vein thrombosis; LV = left ventricle; IVC = inferior vena cava; SCV = superior caval vein. From Figure 2, Lichtenstein DA. Fluid administration limited by lung sonography: the place of lung ultrasound in assessment of acute circulatory failure (the FALLS-protocol). *Expert Rev Respir Med*. 2012;6(2):155–162.

D, which implies suspicion of acute coronary syndrome, are incorrect.

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Ibarra-Estrada MÁ, López-Pulgarín JA, Mijangos-Méndez JC, Díaz-Gómez JL, Aguirre-Avalos G. Respiratory variation in carotid peak systolic velocity predicts volume responsiveness in mechanically ventilated patients with septic shock: a prospective cohort study. *Crit Ultrasound J*. 2015;7:12.

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Learning Objective: Recognize a fluid-responsive patient based on dynamic parameters' assessment.

16. EXPLANATION

D. B and C. While static parameters have been shown to be poor predictors of FR, the maximal and/or minimal end values may suggest patients ability to tolerate fluid. These include very small (<1 cm) inferior vena cava (IVC) measurements; small LV cavity size (LV end diastolic area in parasternal short axis (PSAX) <10 cm^2) or visualization of ventricular-septal "kissing" may suggest hypovolemia. In addition, lung ultrasound findings can be incorporated into decision-making (i.e., the presence of B-lines suggesting pulmonary edema). There are, however, limitations with static measures and confounding conditions that limit their use as they do not necessarily reflect FR status, especially in less obvious hypovolemic states where one must rely on dynamic measures.

One of these measurements is assessing IVC variation during respiration. During spontaneous respiration, the IVC diameter is expected to fall during inspiration due to decrease in intrathoracic pressures and expansion of right heart chambers causing central venous pressure to decrease, as well as due to rise in intra-abdominal pressures from the mechanical changes that occur. However, with positive pressure ventilation (as is the case in mechanically ventilated patients), inspiratory rise in intrathoracic pressure that is transmitted across the RV wall increases more than the RA pressure, thus decreasing transmural pressure and reducing venous return. This effect is exaggerated in hypovolemic states. In mechanically ventilated patients, the *IVC distensibility index* [(max diameter—min diameter)/(min diameter) × 100] value greater than 18% is suggestive of fluid responders with 90% sensitivity and specificity, where patients in the study were mechanically ventilated with tidal volumes of 8.5 cc/kg with positive end-expiratory pressure 4 cm H_2O at 15 breaths per minute, in sinus rhythm, and without abdominal hypertension or cardiopulmonary disease (Airapetian et al., 2015). Other studies have also

examined the use of IVC variation in spontaneously breathing patients, looking at the *IVC collapsibility index* [max diameter—min diameter)/(mean diameter) × 100] with mixed results; one concluded a value >42% predicting an increase in carbon monoxide with fluid administration (Muller et al., 2012) while another suggested a value <40% did not exclude FR (Charron et al., 2006). Therefore, IVC variation measurements are less useful as dynamic measures in nonmechanically ventilated patients.

Stroke volume surrogates are another tool that have been validated in assessing FR. Velocity time integral change (ΔVTI) and maximal velocity change (ΔV_{max}) of the left ventricular outflow tract (LVOT) have been studied, as the LVOT cross-sectional area does not change during the cardiac cycle, and therefore change in stroke volume is directly related to ΔVTI and ΔV_{max}. These measurements are best viewed in apical five-chamber view. LVOT VTI variation cut-off of 20% (Feissel et al., 2001) and peak velocity variation of 12% or greater has been shown to predict fluid responders and nonresponders (Feissel et al., 2001). In both studies, patients were mechanically ventilated with sinus rhythm; these maneuvers have not been shown to reliably predict FR in spontaneously breathing individuals (Feissel et al., 2001).

In regards to the patient's echocardiographic studies, there is marked IVC variation during respiration with distensibility that exceeds the threshold value of >18% as well as peak aortic velocity variation of greater than 12% ([80–50]/[(80 + 50)/2] × 100 = 46%), so fluid administration should be continued.

FURTHER READING

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Charron C, Fessenmeyer C, Cosson C, Mazoit JX, Hebert JL, Benhamou D, Edouard AR. The influence of tidal volume on the dynamic variables of fluid responsiveness in critically ill patients. *Anesth Analg*. 2006;102:1511–1517.

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Learning Objective: Dynamic measures of FR should be employed in serial assessment of patients with septic shock.

17. EXPLANATION

B. Place Foley catheter. Anuric renal failure in the setting of shock has a wide differential; however, obstructive uropathy with elevated post-void residual is one that can be readily diagnosed on ultrasound. Hydronephrosis can be visualized as a dilated renal pelvis in mild cases, followed by dilated calyces in moderate cases and effacement of the renal cortex in severe cases. Furthermore, bladder size can be graded and residual volume can be measured by ultrasound, of which a post-void residual volume of greater than 200 ml would be suggestive of urinary retention.

Though not the case for this patient, Foley catheter dysfunction can also be diagnosed on bedside ultrasound if a significant amount of urine is seen in the lumen of the bladder despite the presence of a Foley balloon. While this patient may require further fluid resuscitation for his shock, the immediate next step should be resolution of his obstruction (choice A is incorrect), as a delay may result in worsening of his renal function (choice D is incorrect). Diuresis in the initial resuscitative phase of septic shock is not appropriate (choice C is incorrect).

FURTHER READING

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Learning Objective: Recognize hydronephrosis and post-void residual in a patient with acute renal failure.

18. EXPLANATION

B. Sedate the patient and start neuromuscular blockade. This case highlights a very common scenario of a patient with late-stage ARDS. The ventilator curve shows a flow volume loop suggestive of dynamic lung hyperinflation and development of "auto-peep." In this setting, further progression of this problem can lead to bradycardia and complete hemodynamic collapse. Sedating the patient and, if needed, restarting neuromuscular blockade may allow the lung to deflate and eliminate dynamic hyperinflation. The presence of lung sliding bilaterally rules out clinically significant pneumothorax, allowing the physician to focus on appropriate management both preventing further deterioration and avoiding unnecessary invasive interventions that may otherwise be performed, such as chest tube placement

(choice D is incorrect). Lung sliding would be absent in a clinically relevant pneumothorax and a stratosphere side on M-mode as shown in Figure 4.10b.

Although prone positioning has been shown to lead to improvement of hypoxia in ARDS, this intervention requires adequate sedation and paralysis and has been shown to be beneficial in early stages of ARDS (choice A is incorrect). A chest CT at this time would not be recommended for this unstable patient (choice C is incorrect).

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Laghi F, Goyal A. Auto-PEEP in respiratory failure. *Minerva Anestesiol*. 2012;78(2):201–221.

Learning Objective: Rule out pneumothorax in an unstable intubated patient at increased risk of developing pneumothorax.

19. EXPLANATION

C. Elevate head of bed 30º, begin hyperventilation, administer IV mannitol and call neurosurgical consultation. Elevated intracranial pressure (ICP) due to cerebral edema is a significant cause of morbidity and mortality in liver failure patients. Ultrasound measurements of the optic nerve sheath diameter (ONSD) can rapidly and accurately predict the presence of elevated ICP so that potentially life-saving management can be initiated when head imaging is not yet readily available. ONSD should be measured 3 mm behind the globe using a linear probe on the closed eyelids of supine patients. Measurements should be made in at least 2 to 3 orthogonal planes and averaged out. An ONSD >5 mm detected ICP >20 cmH2O with a sensitivity of 88% and specificity of 93%. There may be some overlap with the 5 mm cutoff, so it may be best to obtain a baseline measurement on admission for patients at high risk for developing cerebral edema (such as patients with acute stroke, diabetic ketoacidosis, or liver disease) but with normal mental status. This baseline ONSD can then be compared to serial ONSD measurements when patients are altered. Nonconvulsive status epilepticus is on the differential for altered level of consciousness in this patient and may be a cause for his elevated ICP. As such, spot EEG and empiric anti-epileptics should be considered over extended video EEG (choice D is incorrect). Hepatic encephalopathy or worsening uremia may also contribute to his mental status; however, elevated ICP needs be addressed first (choice A is incorrect).

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Learning Objective: Recognize elevated intracranial pressure by optic nerve sheath diameter in a persistently unresponsive patient.

20. EXPLANATION

D. Inotrope with consideration of intra-aortic balloon pump. Postoperative shock carries a wide differential, which can be narrowed with bedside ultrasound. In this case, it shows apical ballooning involving the LV apex, and mid-ventricle is consistent with stress-induced cardiomyopathy, suggesting at least a component of cardiogenic shock. His hypoxic respiratory failure is likely due to acute pulmonary edema; pulmonary vasodilators should be avoided in this setting (choice C is incorrect). Lastly, given his hypoxia in the setting of severely reduced ejection fraction, challenging with fluid and increasing afterload should both be avoided (choices A and B are incorrect).

Takotsubo cardiomyopathy (TTS) can be divided into three classes according to etiology: emotional stress (class 1), physical stress (class 2), and unknown trigger or etiology (class 3). In a recent study by Ghadri et al. class 1 TTS patients were found to have low 30-day and 5-year mortality rates of 2% and 5%, respectively. Patients with class 2 TTS—as in the case of this patient—had mortality rates of 10% at 30 days and 20% at 5 years, which are higher mortality rates than comparable patients with acute coronary syndrome.

FURTHER READING

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Lee JW, Kim JY. Stress-induced cardiomyopathy: the role of echocardiography. *J Cardiovasc Ultrasound*. 2011;19(1):7–12.

Templin C, Ghadri JR, Diekmann J, et al. Clinical features and outcomes of Takotsubo (stress) cardiomyopathy. *N Engl J Med*. 2015;373:929–938.

Learning Objective: Recognize a patient with Takotsubo's cardiomyopathy requiring balloon pump support.

21. EXPLANATION

D. The patient likely has myocarditis. A known complication of viral upper respiratory infections (URIs), especially those caused by influenza, herpes viruses, rhinoviruses, and other cardiotropic viruses, is myopericarditis. Patients presenting with a URI who are persistently tachycardic, fatigued, or dyspneic should be evaluated with POCUS echocardiography to assess for pericardial effusion and/or myocardial depression, with up to 15% having both complications. Once the diagnosis of myocarditis is made, a troponin and BNP may be ordered, along with cardiology consultation for the gold standard noninvasive diagnosis of cardiac magnetic resonance imaging (MRI), if there is doubt. While most cases are mild and self-limiting, patients should be started on high dose nonsteroidal anti-inflammatory drugs or aspirin and admitted for observation.

The patient does not have a pericardial effusion. The parasternal long axis window obtained does not allow for adequate evaluation of RV strain. The parasternal short axis or apical windows are preferred for RV strain or dilation assessment. His CXR is clear, so he does not have a classic pneumonia.

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Learning Objective: Patients presenting with viral syndrome and persistent tachycardia with new evidence of systolic dysfunction should raise concern for myocarditis or pericarditis.

22. EXPLANATION

D. The patient is likely to fail her weaning trial. The patient has evidence of diaphragmatic dysfunction (DD) on thoracic ultrasound. In a recent meta-analysis, this was associated with a sensitivity of 85% and 8.8 odds ratio of spontaneous breathing trial failure as opposed to those without DD.

DD is assessed by measuring the diaphragmatic excursion (DE) and the diaphragmatic thickening fracture (DTF). For DE, place a low-frequency transducer in the

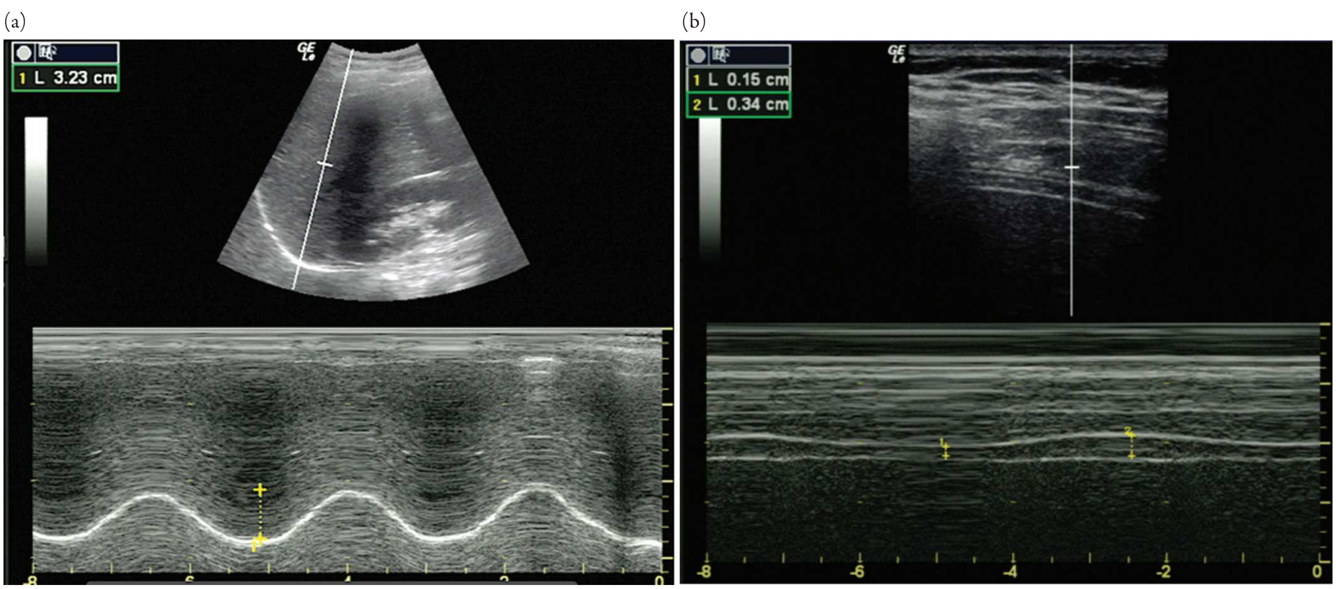

Figure 4.37 (a) **Normal diaphragmatic excursion using M-mode.** (b) **Normal diaphragmatic thickening fraction using M-mode.**

mid to post-axillary line with the indicator pointed cephalad, similar to a FAST window. Place the M-mode line at the juncture of the diaphragm and vertebral column or the costal-diaphragmatic junction. The tracing will reveal peaks with the amplitude of the peaks directly related to the inferior displacement of the diaphragm. A DE value of ≤10–15 mm for normal spontaneous breathing and <25 mm for maximal inspiratory effort is considered abnormal (see Figure 4.37a).

For DTF measurement, a high-frequency transducer is used in the same position as DE measurement, and M-mode is also employed. The diaphragm thickness is less during expiration (DTe) and greater than inspiration (DTi). The DTF is calculated as (DTi – DTe)/DTe. A DTF <30% (with a range of 24%–35% in most studies) is considered abnormal (see Figure 4.37b).

Our patient had a DTF of 4.4% and DE of 2.7 mm, so there is clear diaphragmatic dysfunction.

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Learning Objectives: Identify diaphragmatic dysfunction as part of the assessment for extubation.

23. EXPLANATION

D. Cardiogenic pulmonary edema. The CXR findings show bilateral opacifications of the lungs. This can be secondary to cardiogenic pulmonary edema or ARDS. The definition of ARDS is (a) acute onset, (b) bilateral lung opacifications on CT or x-ray, (c) PaO_2/FiO_2 ratio <300 mmHg, and (d) cannot be due to cardiac failure (left ventricular end diastolic pressure [LVEDP] <18 cm H2O). The patient meets the first 3 criteria for ARDS; however, the forth criteria of ruling out cardiac failure needs to be determined. The patient does not have any overt evidence of systolic cardiac dysfunction on the bedside ultrasound, but diastolic dysfunction cannot be ruled out solely with B-mode. To evaluate for diastolic dysfunction, two components must be examined: (a) the mitral inflow velocity at the mitral valve and (b) the tissue Doppler velocity at the medial or lateral mitral annulus (Figures 2.40 and 2.41). Though this patient had what looks like a normal mitral inflow pattern (E > A), the patient may have either normal diastolic function or "pseudonormal" diastolic function. The patient's septal e' velocity was 5.65 cm/s, indicating moderate diastolic dysfunction or grade II dysfunction. Nagueh et al. in 1997 developed an equation for LVEDP quantification: LVEDP = (1.24 × E/e') + 1.9. Our patient had an E = 90 cm/s and e' of 5.65 cm/s. In this case the LVEDP would equate to 1.24 × (90/5.65) + 1.9 = 21.65 cm H2O. An alternative would be to use E/e' + 4, which would give a value of 20.9. Given this data, our patient does not meet the criteria for ARDS (choice C is incorrect), and the most likely source of hypoxia is from cardiogenic pulmonary edema secondary to diastolic dysfunction. Short axis of echo shows no evidence of D sign or RV failure suggesting massive pulmonary embolism (choice A is incorrect). Primary COPD exacerbations usually have hyperinflated lungs with no significant opacifications on CXR (choice B is incorrect).

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Learning Objective: Echo can be used to help differentiate between ARDS and cardiogenic pulmonary edema.

24. EXPLANATION

A. Administer additional IV fluid. This patient is found to have sepsis with a urinary source, and fluid management is crucial in the management of septic patients. Determining if a patient is fluid responsive can be done using POCUS. A FR test incorporates a dynamic trial method as well as one ultrasound measurement technique (Figure 4.38).

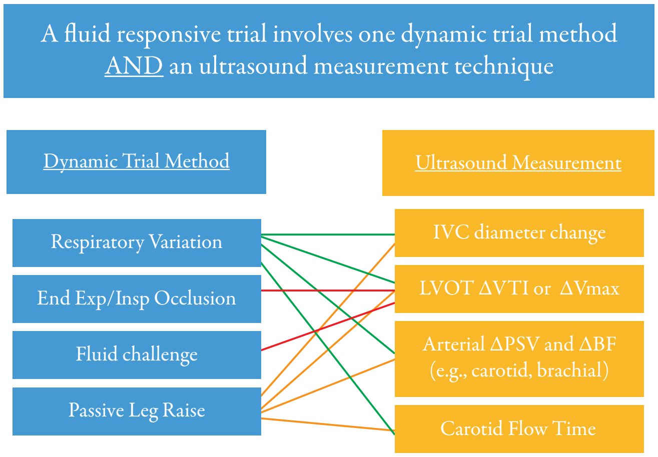

Figure 4.38 **Dynamic trial methods and corresponding ultrasound measurement techniques that can be used.** Note that the ultrasound measurement occurs before (pre) and after (post) the dynamic trial method, and the % change is used as a predictor for fluid responsiveness. The colored lines represent well known pairings of dynamic trial and ultrasound measurement methods, but is not intended to be entirely inclusive, such as non-ultrasound measurements like those involving arterial lines.

In spontaneously breathing patients, the PLR maneuver can help predict FR (Maizel, 2007). Figure 4.39 details how to properly perform the PLR test. Maizel et al found that if the echocardiographic cardiac output or stroke volume increases by more than 12% with PLR, it has been shown to predict FR with 69% sensitivity and 89% specificity. The SV percentage calculation = $(VTI_{post\text{-}PLR} - VTI_{pre\text{-}PLR})$/mean VTI. The SV percentage in our case = (30.6 – 24)/[(30.6 + 24)/2] = 24.2% change. This is greater than 12%, suggesting that the patient would be fluid responsive and would benefit from an additional IV fluid bolus. PLR combined with cardiac output or stroke volume measurements is likely the best test for fluid responsiveness in spontaneously breathing patients. For mechanically ventilated patients, other techniques are also available. Respiratory changes in peak LVOT VTI velocity greater than 12% has been correlated with FR in mechanically ventilated patients (Feissel 2001). Of note, the patients in this study were paralyzed and set on high tidal volumes (8–10 mL/kg) to ensure the differences in peak velocities between inspiration and expiration could be detected. Another technique in mechanically ventilated patients involves using the combined end-expiratory and end-inspiratory occlusions and measuring changes LVOT VTI with echocardiography (Jozwiak, 2017). To perform this test, the LVOT VTI was measured after 15 seconds of end-inspiration occlusion and another LVOT VTI was measured after 15 seconds of end inspiration occlusion. Occlusions should be separated by 1 minute. If the percentage change is greater or equal to 13% between these two values, then it would predict that a patient is fluid responsive with a sensitivity of 93% and specificity of 93%. It has also been found that an increase in LVOT VTI by greater than

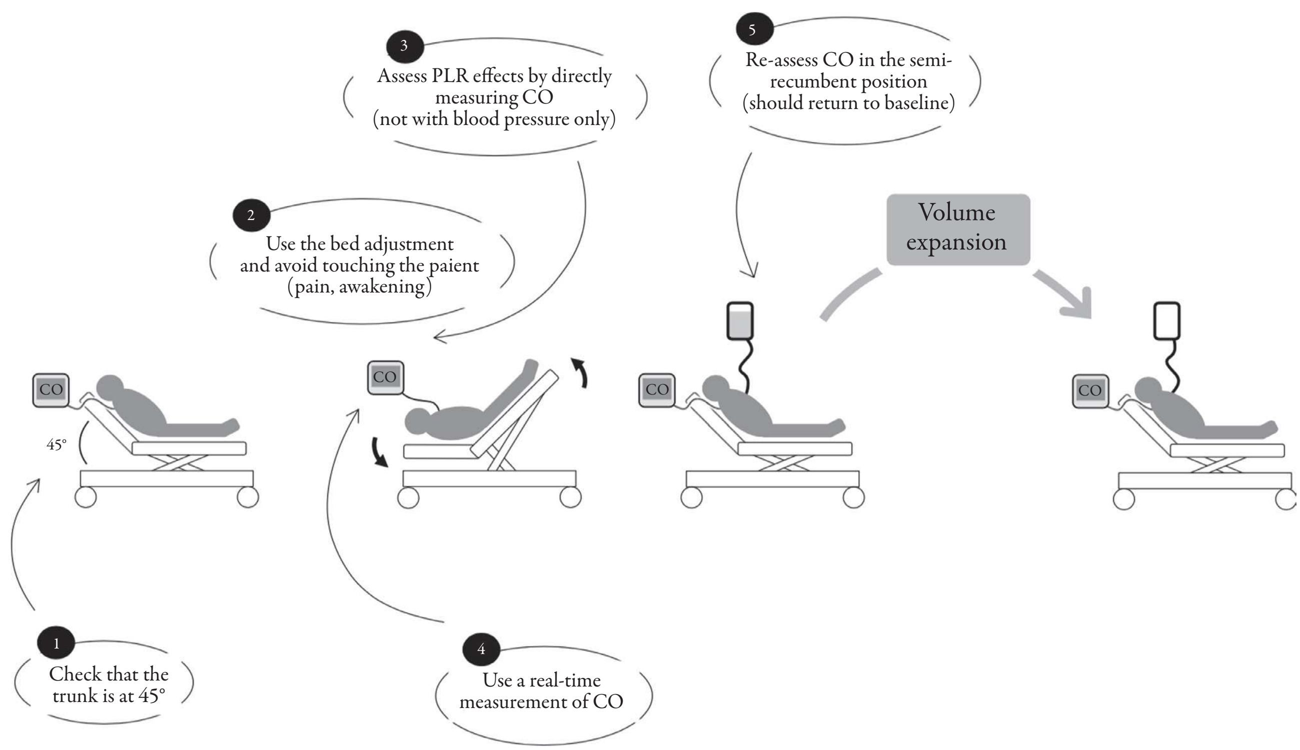

Figure 4.39 **How to perform passive leg raise.** CO = cardiac output; PLR = passive leg raise. From Figure 1 of Monnet X, Teboul J-L. Passive leg raising: five rules, not a drop of fluid! *Crit Care*. 2015;19:18.

6% when a direct fluid bolus of 50 ml is given over 10 seconds can predict FR with a sensitivity of 93% and specificity of 91% (Wu, 2014). The patient is still fluid responsive and fluid status should usually be optimized prior to initiation of vasopressors (choices B and C are incorrect). Echo shows the patient to be hypovolemic, not hypervolemic, hence diuresis would worsen the clinical scenario (choice D is incorrect).

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Learning Objective: Fluid responsiveness: PLR, fluid challenge, End expiratory occlusion test.

25. EXPLANATION

C. Perform compressions more caudally. The arrow in the ultrasound image points to the area of maximal impact at the LVOT causing impedance of forward blood flow during chest compressions. It has been shown that point-of-care TEE is feasible in cardiac arrest patients (Parker, 2018). In addition to helping to rule out emergent conditions, TEE in cardiac arrest can provide continuous imaging regarding depth of chest compressions and the area of maximal compression (AMC). Hwang et al. performed continuous TEE during CPR in 34 patients and found that 100% of these patients had significant narrowing of the LVOT using the American Heart Association guidelines for CPR. Hwang et al. observed LVOT narrowing resolved when the hand position is placed more caudal. This caudal shift in hand position directs the AMC to the left ventricle instead of the LVOT, thereby producing more forward blood flow with chest compressions. This TEE image does not support stopping chest compressions (choice A is incorrect). The area of maximal compression is not in an optimal position (choice B is incorrect). Deeper chest compressions would not help forward flow in this patient since the area of maximal impact is over the LVOT and would likely cause more obstruction and possibly reduce forward flow (choice D is incorrect).

FURTHER READING

Hwang SO, Zhao PG, Choi HJ, et al. Compression of the left ventricular outflow tract during cardiopulmonary resuscitation. *Acad Emerg Med*. 2009;16(10):928–933. doi:10.1111/j.1553-2712.2009.00497.x.

Parker BK, Salerno A, Euerle BD. The use of transesophageal echocardiography during cardiac arrest resuscitation: a literature review. *J Ultrasound Med*. 2018 Oct. doi:10.1002/jum.14794.

Learning Objective: Ultrasound for compressions and cardiac arrest.

26. EXPLANATION

A. The patient has a low likelihood of ROSC. The patient in this study has cardiac standstill identified on the ultrasound. An early study found that cardiac arrest patients found to have cardiac standstill on bedside ultrasound had a 100% positive predictive value of death in the ED (Blaivas, 2001). Subsequent studies, however, found that patients with cardiac standstill are extremely unlikely to have ROSC but still have a 0.6% to 2.4% chance of ROSC (Gaspari, 2016; Blyth, 2012). Patients most likely to have ROSC with cardiac standstill are those who have v-fib with no detectable motion on bedside ultrasound. The benefits of bedside ultrasound during cardiac arrest have also been questioned given the delays they can cause in chest compressions. The mean duration of pulse checks for the ultrasound group versus the non-ultrasound group was 17 seconds versus 11 seconds. Ultrasound-trained physicians, however, had significantly shorter CPR pulse checks than nontrained physicians (Clattenburg, 2018). The increase in pulse checks is likely from the physician delaying reinitiation of chest compressions to try to interpret the images. Breitkreutz et al. suggest a maximum limit of 10 seconds to perform the bedside echocardiogram during CPR pulse checks. During those 10 seconds a video should be saved and interpretation should be performed in between pulse checks and not during pulse checks. While there is a small likelihood of ROSC, it is not zero (choice B is incorrect). The monitor shows asystole and there is no evidence of fine v-fib on POCUS, so defibrillation is not indicated (choice C is incorrect). The video shows cardiac standstill, which is inconsistent with ROSC (choice D is incorrect).

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Gaspari R, Weekes A, Adhikari S, et al. Emergency department point-of-care ultrasound in out-of-hospital and in-ED cardiac arrest. *Resuscitation*. 2016;109:33–39. doi:10.1016/j.resuscitation.2016.09.018.

Learning Objective: TTE can visualize cardiac standstill, which is associated with a low likelihood of ROSC.

5.

THORACIC ULTRASOUND

Jacob Avila, Calvin Huang, and Vicki Noble

QUESTIONS

1. A 47-year-old male presents with acute shortness of breath that was noted after blunt chest trauma sustained in an motor vehicle collision. Vitals are as follows: blood pressure 107/89, heart rate 109, respiratory rate 30, oxygen saturation 91%. Physical exam demonstrates diminished breath sounds on the right. Which of the following ultrasound findings rules out a pneumothorax?

A. Comet-tail artifacts
B. The absence of lung sliding
C. Subcutaneous emphysema
D. A lung point

2. A 16-year-old female presents with dyspnea that has worsened over the past few days. Symptoms are not worse with exertion and no chest pain is reported. Vital signs are as follows: blood pressure 135/76, heart rate 86, respiratory rate 12, oxygen saturation 99% on room air and temperature of 38.9°C. There is wheezing on all lung fields. Ultrasound examination demonstrates the images shown in Figure 5.1 and Video 5.1 in all lung fields. Which of the following is the most likely diagnosis?

A. Cardiogenic pulmonary edema
B. Hyperinflation of the lungs without pulmonary fibrosis
C. Acute respiratory distress syndrome (ARDS)
D. Moderate to severe asthma exacerbation

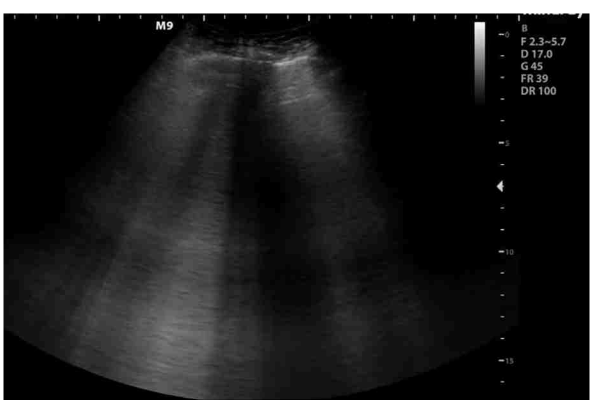

Figure 5.1

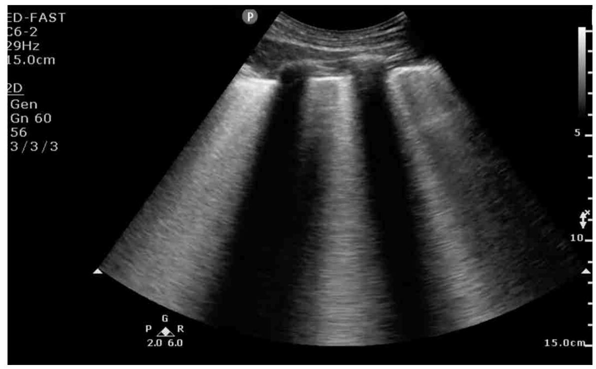

Figure 5.2

3. An 86-year-old male presents with acute shortness of breath and mild chest pain. Bedside ultrasound demonstrates the ultrasound findings in all lung fields, shown in Figure 5.2 and Video 5.2. What is the most likely cause of this sonographic finding?

A. Cardiogenic pulmonary edema
B. Acute chest syndrome
C. Atelectasis
D. Pulmonary contusions

4. A 68-year-old man who is morbidly obese presents with dyspnea. The patient has clear lung sounds, but you see what is shown in Figure 5.3 and Video 5.3 in

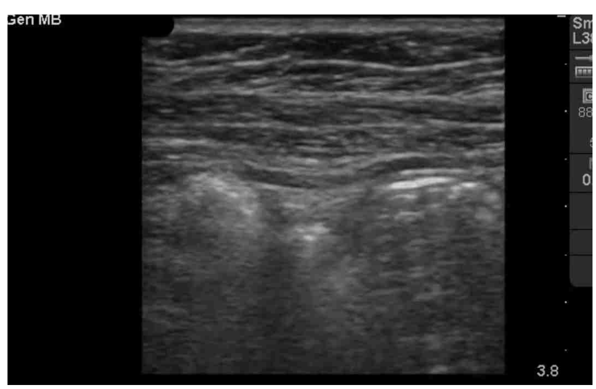

Figure 5.3

the ultrasound at the costal margin. Which is the most likely etiology of the ultrasound findings seen?

A. Pulmonary edema
B. Bowel
C. ARDS
D. Pleural effusion

5. A patient presents with right-sided chest pain and shortness of breath. Vital signs are as follows: blood pressure 105/76, heart rate 118, respiratory rate 32, oxygen saturation 91% on room air. Physical exam demonstrates diminished breath sounds on the right. While using ultrasound, which structure should be evaluated for the presence or absence of a pneumothorax, based on Figure 5.4?

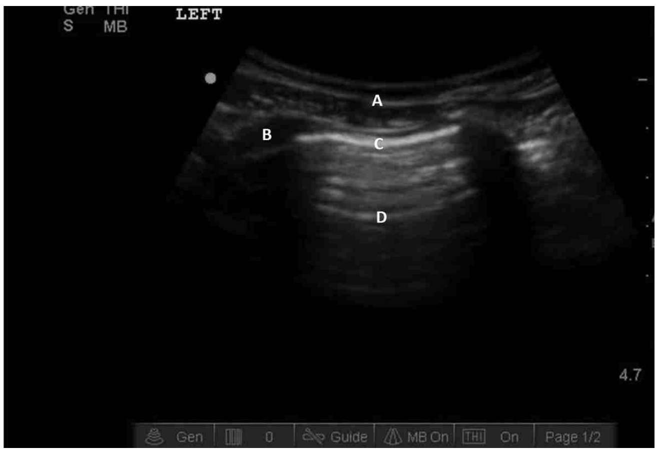

Figure 5.4

A. A
B. B
C. C
D. D

6. A patient presents with right-sided chest pain and shortness of breath. Vital signs are as follows: blood pressure 105/76, heart rate 118, respiratory rate 32, oxygen saturation 91% on room air. Physical exam demonstrates diminished breath sounds on the right, and a bedside ultrasound demonstrates a pneumothorax. Which sonographic artifact is commonly seen in a patient with a pneumothorax?

A. A-lines
B. Shadowing
C. B-lines
D. Edge artifact

7. A patient presents with chest pain and shortness of breath. Vitals signs are as follows: blood pressure 85/56, heart rate 132, respiratory rate 38, oxygen saturation

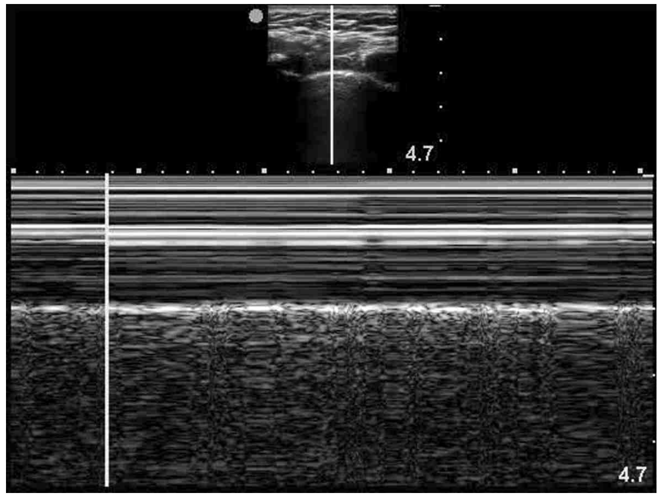

Figure 5.5

91% on room air. Bedside ultrasound demonstrates the shown in Figure 5.5 and Video 5.4 bilaterally and in all lung fields. What is the most likely diagnosis?

A. Apnea
B. Severe obstructive airways disease
C. Pneumothorax
D. Massive pulmonary embolus (PE)

8. An 18-year-old male with a history of Marfan's syndrome presents with right-sided chest pain and shortness of breath. Bedside ultrasound is performed and the finding shown in Figure 5.6 and Video 5.5 is seen. What is represented by this sonographic finding?

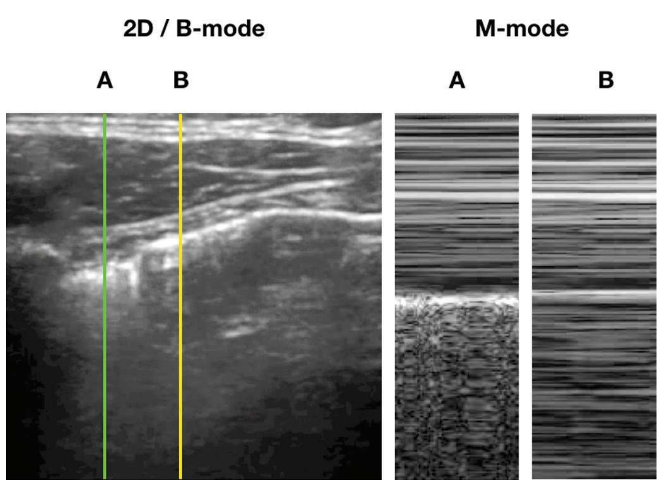

Figure 5.6

A. Location where the pneumothorax begins
B. Interface between the heart and the lung
C. Point where thoracentesis for pleural effusion should be performed
D. Posterior and/or lateral alveolar and/or pleural syndrome point

9. A patient presents with concern for a pneumothorax. Which of the following sonographic findings, when present, rules in a pneumothorax?

A. Lung point
B. B-lines
C. Lung pulse
D. Lung sliding

10. An 87-year-old female is brought in on a backboard after a motor vehicle collision. Her airway, breath sounds, and pulses are intact. She has a Glasgow Coma Scale score of 15. Upon exposure of the patient's chest, you notice that there is bruising on the anterior aspect of her chest wall. In this supine patient, which area of the chest is the most sensitive in ruling out a pneumothorax?

A. Mid-clavicular line, rib spaces 2–3
B. Mid-clavicular line, rib spaces 5–8
C. Anterior axillary line, rib spaces 5–8
D. PLAPS point

11. A 28-year-old male on immunosuppression presents with cough, fever, and pleuritic right-sided chest pain. Vitals signs are as follows: blood pressure 110/89, heart rate 102, respiratory rate 20, oxygen saturation 94% on room air. Bedside ultrasound is performed (see Figure 5.7 and Video 5.6). What is being imaged when a pulmonary consolidation is seen on ultrasound?

Figure 5.7

A. Reverberation artifact
B. Shadowing artifact
C. Mirror image artifact
D. True parenchymal structure

12. A patient presents to the emergency department with dyspnea. Bedside ultrasound is performed and scattered small, <3 cm pleural-based consolidations are seen (see Figure 5.8 and Video 5.7). These findings can be seen in the following situations except for:

Figure 5.8 **Small pleural-based consolidation (arrow).**

A. Pulmonary embolism
B. Pulmonary contusion
C. Pneumothorax
D. Lung cancer

13. A patient was transferred from an outside hospital status post-intubation due to altered mental status. An ultrasound was performed and demonstrated a pleural-based consolidation >3 cm in diameter (see Figure 5.9 and Video 5.8). Which of the following pathologies may manifest as a pleural-based consolidation >3 cm in diameter?

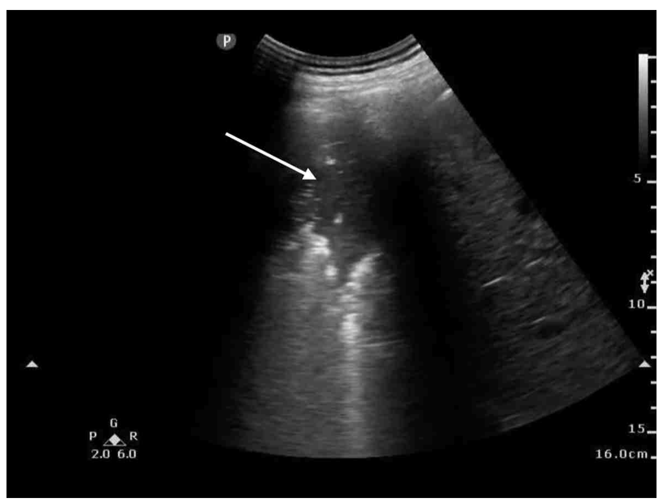

Figure 5.9 **Large pleural-based consolidation (arrow).**

A. Pulmonary embolism
B. Atelectasis
C. Cardiogenic pulmonary edema
D. COPD

14. A patient presents to the emergency department with cough, fever, and shortness of breath. Bedside ultrasound is performed and demonstrates results shown in Figure 5.10, and Video 5.9. Which finding seen here is useful in differentiating between atelectasis and pneumonia?

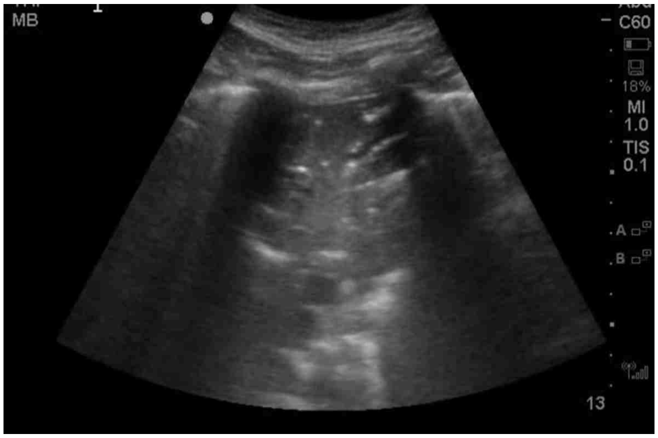

Figure 5.10

A. Static air bronchograms
B. Presence of surrounding B-lines
C. Absence of bronchograms
D. Dynamic air bronchograms

15. A patient presents to the emergency department with cough, fever, and shortness of breath. Bedside ultrasound is performed and demonstrates dynamic air bronchograms (see Figure 5.11 and Video 5.10). What is the most likely mechanism for how dynamic air bronchograms are thought to be generated?

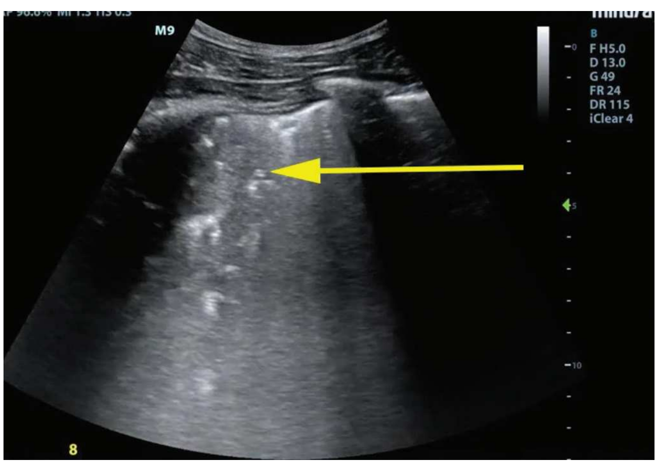

Figure 5.11 **Dynamic air bronchogram (arrow) with B-lines indicative of pneumonia.** See Video 5.10. Adapted from Supplemental Video 2 of Le Neindre A, Mongodi S, Philippart F, Bouhemad B. Thoracic ultrasound: Potential new tool for physiotherapists in respiratory management. A narrative review. *J Crit Care.* 2016;31(1):101–109. doi:10.1016/j.jcrc.2015.10.014.

A. Reverberation artifact seen when air and fluid are in close proximity to each other
B. Reverberation artifact seen when there is a uniform layer of air at 90 degrees to the ultrasound beam
C. Presence of air mixed with fluid or mucous within small airways seen to move with respiration
D. Collapsed small airways that do not move with respiration

16. A 56-year-old male presents to the emergency department with cough, fever, and shortness of breath. Bedside ultrasound is performed and demonstrates the results shown in Figure 5.12 and Video 5.11. What does the finding represent?

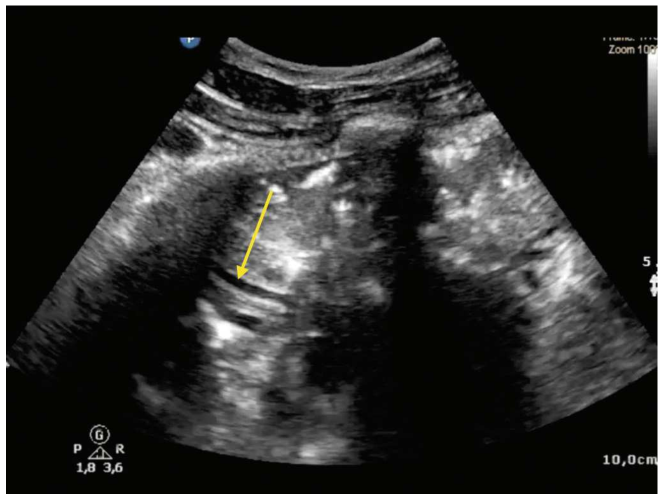

Figure 5.12

A. Presence of air mixed with fluid or mucous within small airways seen to move with respiration
B. Collapsed small airways that do not move with respiration
C. Fluid-filled small airways
D. Presence of extra-pulmonary fluid usually seen in the dependent portions of the lung

17. A 19-year-old female presents with unilateral leg swelling and dyspnea. On review of her medications, she reports taking oral contraceptives. Bedside ultrasound is performed. Which one of the following pathologic pulmonary findings are most commonly described in PE?

A. Mirror sign
B. A-lines
C. Diffuse B-lines
D. <3 cm pleural-based consolidation

18. A 68-year-old patient with a history of lung cancer presents with worsening shortness of breath over the past 3 weeks. On exam you hear decreased breath

sounds of the left lung. You are concerned about a possible malignant pleural effusion. When evaluating a patient for pleural effusion, how can the patient be positioned to increase the sensitivity of the examination?

A. Prone positioning
B. Supine positioning
C. Sitting up at 90 degrees
D. Sitting up at 45 degrees

19. A 72-year-old patient with a history of cancer presents to the emergency department with increasing shortness of breath and pleuritic left-sided, lateral chest pain. Bedside ultrasound is performed to evaluate for pleural effusion. What are the two signs that are used to identify a pleural effusion?

A. Spine sign and B-lines
B. Mirror sign and spine sign
C. Mirror sign and A-lines
D. Spine sign and spleen sign

20. A patient presents from an outside hospital with the diagnosis of a "lung white out" on chest X-ray. Vital signs are as follows: blood pressure 110/89, heart rate 102, respiratory rate 20, oxygen saturation 94% on room air and a temperature of 101.0. An ultrasound is performed and the clip shown in Figure 5.13 and Video 5.12 is obtained. What is the most likely diagnosis?

Figure 5.13

A. Pneumonia
B. Asthma exacerbation
C. COPD exacerbation
D. Pulmonary fibrosis

21. A bedside ultrasound is performed on a patient that confirms the presence of a pleural effusion. The admitting physician asks you to estimate the volume of the pleural effusion. How can the volume of a pleural effusion be quantified?

A. It cannot be quantified.
B. Length of the pleural effusion in the craniocaudal orientation and divided by the cross-sectional area at the apex of the effusion
C. Length of the pleural effusion in the craniocaudal orientation multiplied by the cross-sectional area at the widest portion of the effusion
D. Length multiplied by height and width of the pleural effusion

22. A bedside ultrasound is performed on a patient with metastatic lung cancer and confirms the presence of a pleural effusion. The consulting intensive care medicine physician asks you if there is the presence of a plankton sign on the sonographic evaluation. What is a plankton sign?

A. An artifact generated when air and fluid are in close proximity to each other, such as what is seen in cardiogenic pulmonary edema
B. Formed when a uniform layer of air is seen at 90 degrees to the ultrasound beam
C. A way to describe transudative pleural effusions
D. A way to describe exudative pleural effusions

ANSWERS

1. EXPLANATION

A. Comet-tail artifacts. The pleural line, as imaged sonographically, appears as a thin hyperechoic stripe that is generated by the interface of the parietal and visceral pleura. Comet-tails are generated by the deeper visceral pleura (Figure 5.14a, Video 5.13). This is important in the evaluation of a pneumothorax because comet-tails can only be visualized when the visceral pleura is touching the parietal pleura. In a pneumothorax, the pleural layers are separated by air, so that comet-tails cannot be seen. If the patient has the absence of lung sliding but has visible comet tails, it means that there is no air separating the parietal pleura (essentially the wall of the thoracic cavity) and the visceral pleura (lung surface), which rules out a pneumothorax. It is important to note that, when there is subcutaneous emphysema, comet-tails can be seen. Some refer to these as "E-lines" (Figure 5.14b, Video 5.14) However, these will be seen arising from the soft tissue superficial to the pleura, not from the pleural interface.

Learning Points: When generated from the pleural line, comet-tail artifacts, which include B-lines, rule out pneumothorax.

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Soldati G, Testa A, Silva FR, Carbone L, Portale G, Silveri NG. Chest ultrasonography in lung contusion. *Chest*. 2006;130(2):533–538.

Keywords/Tags: Lung, comet-tails, pleura, pneumothorax

2. EXPLANATION

D. Moderate to severe asthma exacerbation. In the absence of pulmonary fibrosis (which can cause B-lines), hyperinflation of the lungs will generate a pleural line with only A-lines beneath it (Figure 5.15, Video 5.15). Additionally, diminished lung sliding may be noted due to decreased excursion of the already hyperinflated lung. Cardiogenic pulmonary edema is probably the most commonly discussed cause of diffuse B-lines. ARDS also commonly has diffuse B-lines; additionally, skip areas, pleural effusions, and focal consolidations may be seen. A recent study by Dankoff et al. demonstrated that B-lines can be seen in moderate to severe asthma exacerbations. There is debate as to exactly what is the cause of the B-lines; however, it seems the most likely cause is viral pulmonary infection leading to the exacerbation as well as the to the generation of B-lines.

Learning Points: B-lines can be seen when pulmonary edema, ARDS, or severe asthma exacerbation are present.

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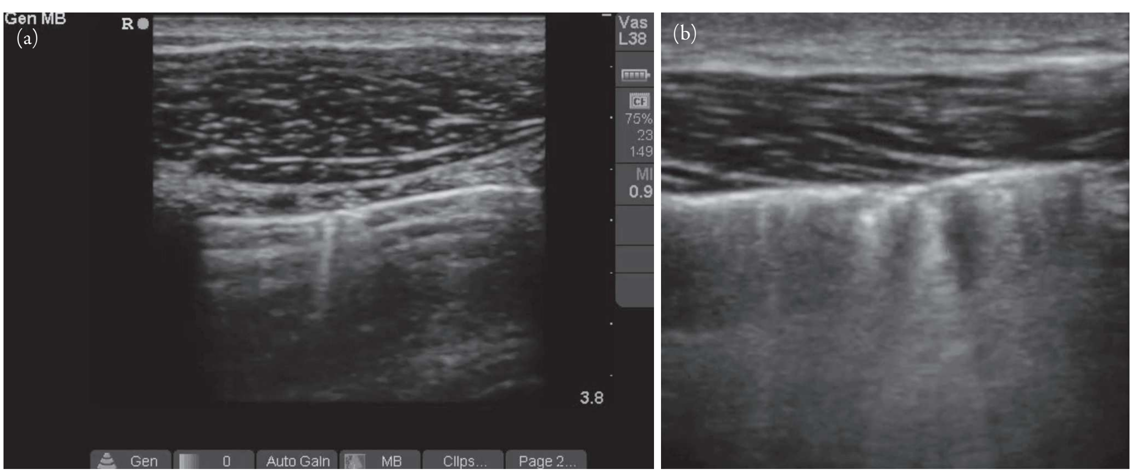

Figure 5.14 (a) **Comet tail artifact.** (b) **"E-lines" signifying subcutaneous emphysema.** Notice that "E-lines" arise from the subcutaneous tissue superficial to the pleura and not from the pleural line itself.

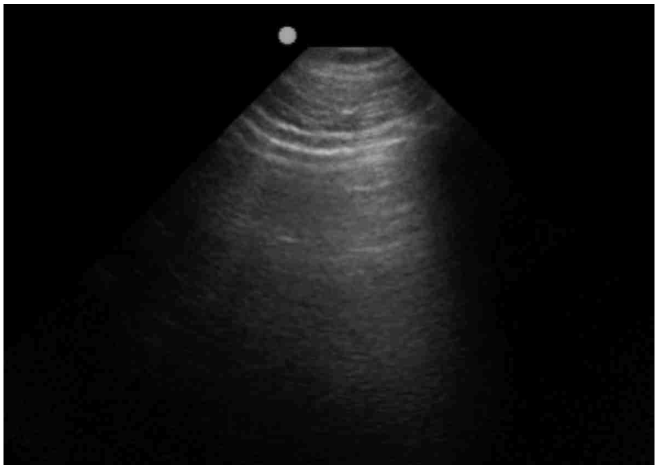

Figure 5.15 **Normal lung sliding (see Video 5.3) with A-lines.**

Volpicelli G, Elbarbary M, Blaivas M, et al. International evidence-based recommendations for point-of-care lung ultrasound. *Intensive Care Med*. 2012;38(4):577–591. doi:10.1007/s00134-012-2513-4.

Keywords/Tags: Lung, b-lines, pulmonary edema, ARDS, asthma

3. EXPLANATION

A. Cardiogenic pulmonary edema. B-lines are generated whenever the density of the lungs increases above normal. This is due to a reverberation artifact at the most superficial aspect of the lungs. This increase in density that creates B-lines is often fluid but can also be due to atelectasis, pneumonia, acute chest syndrome, and pulmonary fibrosis, among others. Diffuse B-lines, defined as 3 or more B-lines per rib space, and seen in 2 or more zones per side, is often seen in cardiogenic pulmonary edema.

Learning Points: The most common etiology of diffuse B-lines in an acutely dyspneic patient is cardiogenic pulmonary edema.

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Volpicelli G, Elbarbary M, Blaivas M, et al. International evidence-based recommendations for point-of-care lung ultrasound. *Intensive Care Med*. 2012;38(4):577–591. doi:10.1007/s00134-012-2513-4.

Keywords/Tags: Lung, B-line, pulmonary edema, atelectasis

4. EXPLANATION

B. Bowel. B-lines are seen when fluid and air are seen in close proximity to each other, creating a reverberation artifact. The ultrasound in the case shows B-lines but also an irregular contour and peristalsis that is specific to bowel. The exact etiology of how B-lines are generated is not definitively known, but there are two predominant theories. Both involve interactions between the interfaces of air and fluid/tissue. The exact etiology is not as important as knowing in which situations they are formed. We typically think about B-lines in the setting of cardiogenic pulmonary edema, but B-lines can be seen in a multitude of other pathologies including (but not limited to) pneumonia, atelectasis, high altitude pulmonary edema, acute chest syndrome, and pulmonary contusions. Additionally, B-lines are very commonly seen in the intestines.

Learning Points: B-lines are generated by the proximity of fluid and air, and are not specific to the lung/pleural line.

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Volpicelli G, Elbarbary M, Blaivas M, et al. International evidence-based recommendations for point-of-care lung ultrasound. *Intensive Care Med*. 2012;38(4):577–591. doi:10.1007/s00134-012-2513-4.

Keywords/Tags: Lung, B-line, artifact, bowel

5. EXPLANATION

C. C. The presence or absence of a pneumothorax can be evaluated by looking at the pleural line (C). It is a highly echogenic line that is generated by the interface of the visceral and parietal pleura. It will be deep to the subcutaneous tissues (A). The appearance of two rib shadows (B) abutting the pleural line is known as the "bat sign" (Lichtenstein, 2012). Furthermore, A-lines (D) are reverberation artifacts between the probe and the pleural line. They can be noted at multiples of the depth between the probe and the pleural line.

Learning Points: The pleural line is identified as a hyperechoic line parallel to the probe surface just below the level of the rib surfaces.

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Lichtenstein DA, Mauriat P. Lung ultrasound in the critically ill neonate. *Curr Pediatr Rev*. 2012;8(3):217–223. doi:10.2174/157339612802139389.
Noble VE, Nelson BP. *Manual of Emergency and Critical Care Ultrasound*. 2nd ed. Cambridge, UK: Cambridge University Press; 2011:191–202.

Keywords/Tags: Lung, A-line, pleural line, bat sign

6. EXPLANATION

A. A-lines. A-lines are generated any time there is a uniform layer of air underneath the probe. This can be seen in a normal lung as well as in a patient with a pneumothorax. B-lines are generated from the visceral pleura and therefore would not be visible in the setting of a pneumothorax. Like comet-tails, the appearance of B-lines rules out a pneumothorax in the area being imaged. Shadowing is seen when the ultrasound beam is absorbed by a structure, such as a rib, and is generally not helpful in the evaluation of a pneumothorax. An edge artifact is formed when the ultrasound beam refracts around the curved edge of a cystic, fluid-filled structure.

> **Learning Points:** A-lines are caused by reverberation between the probe surface and the pleural line. They do not rule out a pneumothorax.

REFERENCE

Lichtenstein DA, Mezière GA. Relevance of lung ultrasound in the diagnosis of acute respiratory failure: the BLUE protocol. *Chest*. 2008;134(1):117–125. doi:10.1378/chest.07-2800.

Keywords/Tags: Lung, A-line, B-line, edge, artifact, shadowing

7. EXPLANATION

D. Massive pulmonary embolus (PE). Massive PE will show right heart strain and may show small (<3 cm) pleural consolidations consistent with focal atelectasis/infarction from distal emboli. Lung sliding will still be present, and B-lines are generally not seen. The other answer choices will have reduced or no lung sliding (Figure 5.16, Video 5.16). Severe obstructive airways disease and apnea may demonstrate the absence of lung sliding due to the lung parenchyma not moving. If the lung parenchyma does not move, there will be no sonographic lung sliding. Pneumothorax is the prototypical pathology in which lung sliding will be absent.

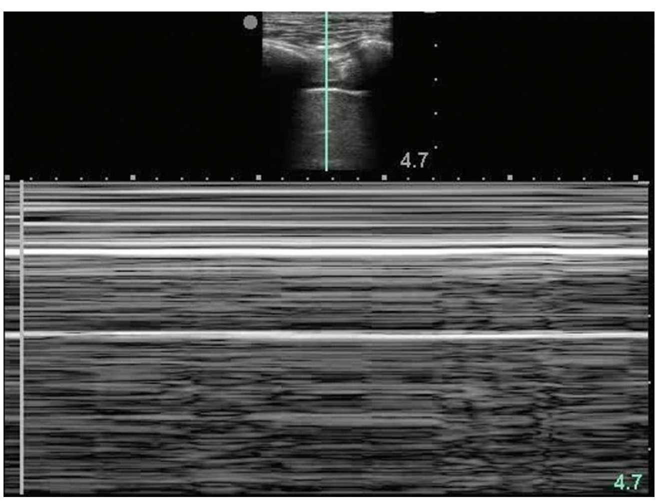

Figure 5.16 **Absence of lung sliding on M-mode.**

The increased temporal resolution in M-mode can be used to help with evaluation of pneumothorax, especially for novice sonographers (Avila et al.). Figure 5.5 shows the normal pleural sliding seen as increased granularity deep to the pleural lining on the M-mode tracing, a pattern described as "sky-ocean-beach." The sky is the subcutaneous tissue, the ocean is the muscle layer, and the sandy beach denotes motion deep to the pleural line, which appears as the wave froth or sea foam. A lung profile on M-mode with absence of pleural sliding has no such granularity but fixed horizontal lines throughout, a pattern called the "bar code" or "stratosphere" sign, as seen in Figure 5.16.

> **Learning Points:** Lack of lung sliding is not specific to pneumothorax and can also be seen in other situations such as apnea or severe chronic obstructive pulmonary disease (COPD) with lung hyperinflation.

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Keywords/Tags: Lung, sliding, pneumothorax, apnea, COPD

8. EXPLANATION

A. Location where the pneumothorax begins. The ultrasound in the case reveals a "lung point" sign. A lung point represents the area in the thorax where you see lung sliding (no pneumothorax, point A) and the absence of lung sliding (pneumothorax, point B) in the same view. This sign is thought to be highly specific for a pneumothorax and can be used to estimate the size of the pneumothorax by mapping out the border of the extra-pulmonary air pocket. The lung point sign can be seen in both B-mode and M-mode. The interface between

the heart and lung sometimes generates a false-positive lung point. This represents the area (typically on the left chest) where the lung pleura (sliding) and the heart (no sliding) come in contact. The point where thoracentesis should be performed is wherever the largest and most inferior pocket of fluid is located and is not a lung point. The posterior and/or lateral alveolar and/or pleural syndrome (PLAPS) point is an anatomical location located at the posterior axillary line and the diaphragm and not helpful in the evaluation of a pneumothorax.

Learning Points: A lung point represents the border of a pneumothorax. Its presence is almost pathognomonic for pneumothorax.

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Lichtenstein D, Mezière G, Biderman P, Gepner A. The "lung point": an ultrasound sign specific to pneumothorax. *Intensive Care Med*. 2000;26(10):1434–1440.

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Keywords/Tags: Lung, point, pneumothorax

9. EXPLANATION

A. Lung point. The presence of a lung point is used to rule-in a pneumothorax. B-lines are generated from the visceral pleura. If B-lines can be seen, it means there is no air separating the visceral and parietal pleura. This rules out a pneumothorax (Lichtentein, 1999). The lung pulse (Figure 5.17, Video 5.17) was originally described to evaluate for atelectasis but can also be applied to rule out pneumothorax (Lichtenstein, 2003). It is seen when the heart movement is transmitted through the lung parenchyma to the visceral pleura. This is seen as a rhythmic back and forth movement of the pleural line that is in sync with the patient's pulse. This movement can only be seen if the visceral pleura is touching the parietal pleura, thus excluding pneumothorax. The presence of lung sliding means that the visceral and parietal pleura are touching thereby excluding a pneumothorax.

Learning Points: In addition to lung sliding, B-lines and lung pulse can rule out a pneumothorax.

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Keywords/Tags: Lung, point, pneumothorax, pulse, B-lines

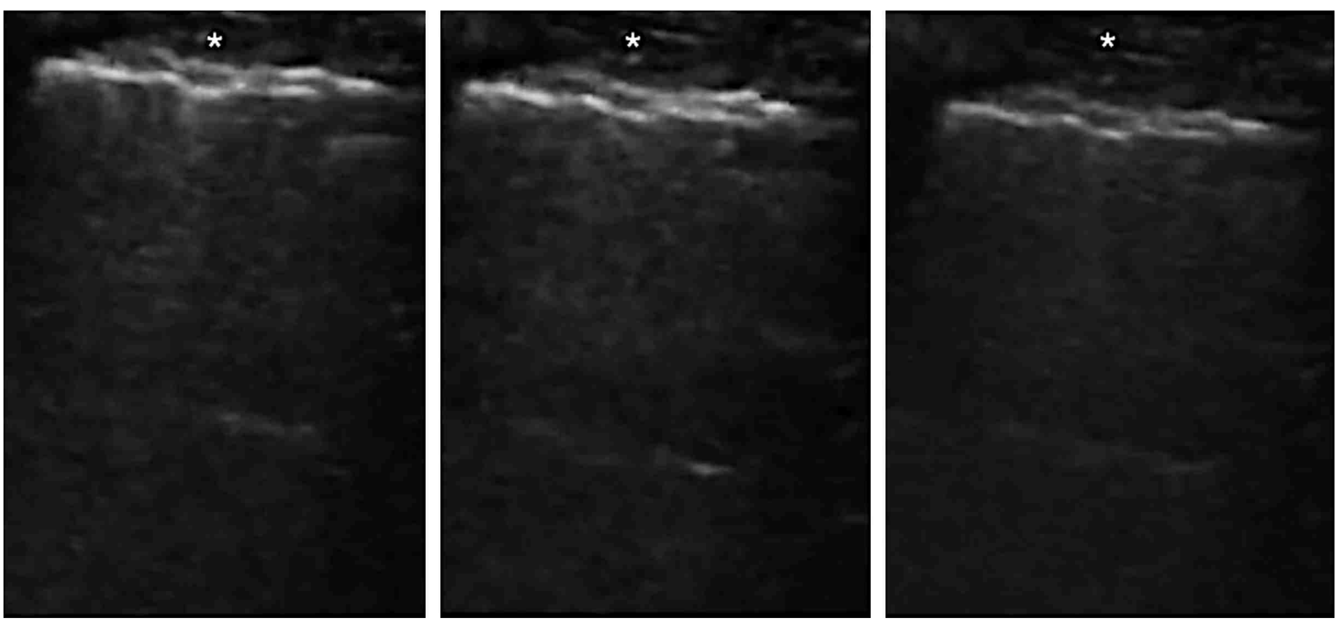

Figure 15.17 **Lung pulse sign, seen as subtle rhythmic movements (*) due to cardiac pulsation.**

10. EXPLANATION

B. Mid-clavicular line, rib spaces 5–8. In a computed tomography (CT) study of traumatic pneumothoraces, the most common location for a pneumothorax to be present was in rib spaces 5–8 due to the anatomical shape of the chest wall and the fact that air tends to rise to the most anterior part of any enclosed system. While that area is typically the most sensitive, a systematic survey of the entire anterior chest wall should be performed to definitively rule out a pneumothorax. While rib spaces 2–3 are commonly reported to be the ideal place to start the search for a pneumothorax, it is not the most sensitive area. The anterior axillary line is generally too lateral of a survey area to find smaller pneumothoraces. The PLAPS point is also generally too lateral of a survey area to find smaller pneumothoraces.

> **Learning Points:** The most anterior point of the chest which corresponds to the 5–8th rib spaces in the mid-clavicular line is most sensitive for detecting a pneumothorax.

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Keywords/Tags: Lung, pneumothorax, trauma

11. EXPLANATION

D. True parenchymal structure. When the density of the lung reaches a certain point, there is no more residual air in the lung tissue, leaving just the pulmonary parenchyma. Without air obstructing the sound waves, the actual pulmonary parenchyma is visualized. This is referred to as hepatization of the lung, because the lung has similar appearance to the liver on ultrasound. Shadowing artifact is seen when the sound beam is absorbed by a structure (bone) or reflected by a structure (air). Reverberation artifact is seen with both A-lines and B-lines. B-lines can be seen in early bacterial pneumonia, viral pneumonia, or around the periphery of a consolidation. A-lines are seen when the lung is predominately air filled. Mirror image artifact is seen in the absence of a consolidation or pleural effusion in the dependent portions of the lung and is generated when the sound waves encounter a significant change in density. The classic example of mirror image artifact is at the diaphragm where the lung/liver or lung/spleen interface exists (Figure 5.18). Note that the vertebral column does not extend pass the diaphragm (*), so the apparent liver superior to the diaphragm (arrow) is a mirror image.

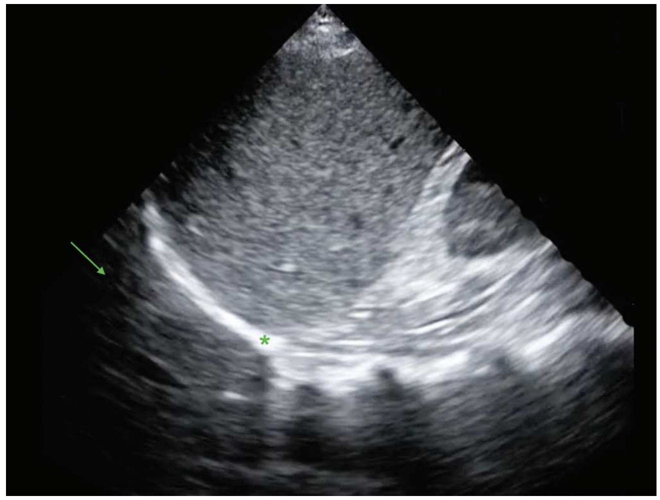

Figure 5.18 **Mirror image artifact of the right upper quadrant.**

> **Learning Points:** The true lung parenchyma can be visualized sonographically when fluid replaces air in the small airways. This is most commonly seen with pneumonia.

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Reissig A, Kroegel C. Sonographic diagnosis and follow-up of pneumonia: a prospective study. *Respiration*. 2007;74(5):537–547.

Keywords/Tags: Lung, consolidation, artifact, mirror image, shadowing

12. EXPLANATION

C. Pneumothorax. Small pleural-based consolidations have previously been called subpleural consolidations, but this phrase does not adequately describe the finding since all consolidations that can be seen by ultrasound are subpleural. Small pleural-based consolidations are arbitrarily defined as <3 cm in diameter and arise from the visceral pleura. Miller et al. were among the first to visualize them on ultrasound in 1967, and they described them as peripheral lesions caused by pulmonary embolism. Mathis et al showed that 2 or more triangular-shaped or round consolidations located just deep to the pleura was associated with 75% sensitivity and 95% specificity for pulmonary embolism. In addition to PE,

pulmonary contusions and lesions from lung cancer are associated with these small pleural-based consolidations. In the setting of a pneumothorax, pleural sliding is not seen due to separation of the pleural layers with free air.

Learning Points: Pulmonary embolism, pulmonary contusion, and pulmonary cancer can all generate small, <3 cm pleural-based consolidations.

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Keywords/Tags: Lung, pleural, consolidation, pulmonary, embolism, contusion, pneumothorax

13. EXPLANATION

B. Atelectasis. Pneumonia, large pulmonary cancers, and atelectasis can cause large pleural-based consolidations >3 cm in diameter. Atelectasis is more commonly seen in the dependent portions of the lung. Pulmonary emboli can cause small pleural consolidations, but generally are not >3 cm unless the area of infarction is very large. Cardiogenic pulmonary edema usually manifests as diffuse sonographic B-lines. COPD usually does not demonstrate any specific ultrasound findings. Diminished lung sliding and diaphragmatic movement can occasionally be seen. If the patient has a concomitant viral illness or the presence of pulmonary fibrosis, B-lines may be present.

Learning Points: Large (>3 cm) pleural-based consolidation can be caused by atelectasis, pneumonia, and lung cancer/mass.

REFERENCES

Dietrich CF, Mathis G, Cui XW, Ignee A, Hocke M, Hirche TO. Ultrasound of the pleurae and lungs. *Ultrasound Med Biol*. 2015;41(2):351–365.

Gardelli G, Feletti F, Nanni A, Mughetti M, Piraccini A, Zompatori M. Chest ultrasonography in the ICU. *Respir Care*. 2012;57(5):773–781. doi:10.4187/respcare.01743.

Keywords/Tags: Lung, pleural, consolidation, pulmonary embolism, atelectasis, pneumonia

14. EXPLANATION

D. Dynamic air bronchograms. Static air bronchograms are thought to represent collapsed airways in lung parenchyma and are seen as hyperechoic lines and dots inside a hypoechoic lung that do not move as a result of a collapsed bronchial tree in that region. With respirations, they are still collapsed and therefore appear static. They are usually seen in atelectasis and sometimes in pneumonia. However, it is unclear whether they are static because of an inherent change in the architecture of the area imaged or because of the underlying cause of hypoventilation. Dynamic air bronchograms are thought to represent fluid, pus, or mixed fluid/air in small airways and are visualized as hyperechoic lines and dots within hypoechoic lung parenchyma that move with respiration. These are thought to be pathognomonic for pneumonia. However, only a few small studies by experts exist that show a reliable distinction between static and dynamic types. Surrounding B-lines can be seen in the lung tissue surrounding both atelectasis and pneumonia.

Learning Points: The presence of dynamic air bronchograms are pathognomonic for pneumonia.

REFERENCES

Lichtenstein D, Mezière G, Seitz J. The dynamic air bronchogram: a lung ultrasound sign of alveolar consolidation ruling out atelectasis. *Chest*. 2009;135(6):1421–1425. doi:10.1378/chest.08-2281.

Targhetta R, Chavagneux R, Bourgeois JM, Dauzat M, Balmes P, Pourcelot L. Sonographic approach to diagnosing pulmonary consolidation. *J Ultrasound Med*. 1992;11(12):667–672.

Weinberg B, Diakoumakis EE, Kass EG, Seife B, Zvi ZB. The air bronchogram: sonographic demonstration. *AJR Am J Roentgenol*. 1986;147(3):593–595.

Keywords/Tags: Lung, dynamic air bronchograms, atelectasis, pneumonia

15. EXPLANATION

C. Presence of air mixed with fluid or mucous within small airways seen to move with respiration. B-lines are generated when air and fluid are in close proximity to each other, such as what is seen in cardiogenic pulmonary edema. Static air bronchograms are seen with collapsed small airways, such as atelectasis, that do not move with respiration. This will be seen as small, hyperechoic flecks within the pulmonary parenchyma. This may occur in atelectasis. A-lines

are generated when a partial reflector, such as a uniform layer of air, is seen at 90 degrees to the ultrasound beam. This is typically seen in a predominately air-filled lung but can be seen in the intestines or if there is subcutaneous air.

Learning Points: Dynamic air-bronchograms are caused by fluid moving within the small airways of the lung and are highly suggestive of pneumonia.

REFERENCES

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Keywords/Tags: Lung, dynamic air bronchogram, pneumonia

16. EXPLANATION

C. Fluid-filled small airways. The finding on the ultrasound (yellow arrow) shows fluid-filled small airways (fluid bronchograms), which likely represent progression from dynamic air bronchograms in which all the air in the small airways have been reabsorbed. Fluid bronchograms are hypoechoic tubular structures seen in a consolidated lung. Dynamic air bronchograms are visualized as hyperechoic lines and dots within hypoechoic lung parenchyma that move with respiration. The differential diagnosis for fluid bronchograms includes isolated pneumonia, post obstructive pneumonitis, proximal tumors, and impacted secretions (Koh, 2002). Static air bronchograms are thought to represent collapsed airways in lung parenchyma and are seen as hyperechoic lines and dots inside a hypoechoic lung that do not move independently of the lung. Fluid bronchograms may be confused with visible pulmonary blood vessels. An easy way to distinguish between them is by placing color flow Doppler and looking for flow. Pleural effusions are the presence of extra-pulmonary fluid usually seen in the dependent portions of the lungs.

Learning Points: Fluid bronchograms are a progression of dynamic air-bronchograms and they do not represent vascular flow.

REFERENCES

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Keywords/Tags: Lung, fluid bronchogram, pneumonia

17. EXPLANATION

D. <3 cm pleural-based consolidation. These have been previously called subpleural consolidations, but this phrase can be ambiguous because any consolidation seen by ultrasound is subpleural (Figure 5.19, Video 5.18). There have been many publications describing the sonographic finding in the setting of a PE. This sonographic finding is not necessarily sensitive nor specific when compared to CT but may help in the diagnosis if a gold-standard diagnostic test is unavailable. A-lines and mirror image artifact are seen any time there is predominantly air in the thorax. These findings may be seen in a patient with a pneumothorax but are not the most commonly described sonographic pathologic findings in PE. Diffuse B-lines are not commonly described sonographic findings seen in PE although focal B-lines may be present. Diffuse B-lines are more commonly seen in disease processes that affect a more diffuse surface of the lung, such as ARDS or cardiogenic pulmonary edema.

Figure 5.19 **Pleural-based consolidation (yellow arrow).**

Learning Points: <3cm pleural-based consolidations are the most common sonographic finding of the lung in PE.

REFERENCE

Squizzatrefo A, Rancan E, Dentali F, et al. Diagnostic accuracy of lung ultrasound for pulmonary embolism: a systematic review and meta-analysis. *J Thromb Haemost*. 2013;11(7):1269–1278. doi:10.1111/jth.12232.

Keywords/Tags: Lung, pulmonary embolism, A-lines, B-lines, mirror sign, artifact, consolidation

18. EXPLANATION

C. Sitting up at 90 degrees. This positioning will bring the fluid laterally toward the typical place the probe is placed, which is the posterior or mid-axillary line right at the level of the diaphragm (Figure 5.20). This is also the ideal positioning for performing a thoracentesis if the patient can tolerate it.

Figure 5.20 **Patient positioning to maximize sensitivity for evaluation of pleural effusion.**

> **Learning Points:** A seated position at 90 degrees will position pleural fluid in a way that maximizes the sensitivity of detection.

REFERENCE

Dietrich CF, Mathis G, Cui XW, Ignee A, Hocke M, Hirche TO. Ultrasound of the pleurae and lungs. *Ultrasound Med Biol*. 2015;41(2):351–365.

Keywords/Tags: Lung, pleural effusion

19. EXPLANATION

B. Mirror sign and spine sign. The presence of a mirror sign is useful in ruling out the presence of a pleural effusion. This is seen when the image cephalad to the diaphragm is a mirror image of the area caudal to the diaphragm (Figure 5.21a, Video 5.19). This happens whenever there is a low-density structure (air-filled lung) right next to a higher density structure (liver/spleen). The spine sign is useful in ruling in a pleural effusion. In an air-filled lung, the spine cannot be seen above the diaphragm because the air molecules scatter the sound waves and prevent them from reaching the thoracic vertebral bodies. However, if there is a pleural effusion, the extrapulmonary fluid helps transmit the sound waves to the thoracic vertebral bodies, thereby elucidating their location (Figure 5.21b, Video 5.20). A-lines are formed when a uniform layer of air is seen at 90 degrees to the ultrasound beam. This is typically seen in a predominately air-filled lung but can also be generated by the intestines or by subcutaneous air. B-lines are generated when small pockets of air and fluid are adjacent to one another, such as what is seen in cardiogenic pulmonary edema. The spleen sign is not a previously describe sign used to rule in or rule out pleural effusions.

> **Learning Points:** The mirror image artifact/mirror sign and the spine sign help determine the presence or absence of pleural fluid.

REFERENCES

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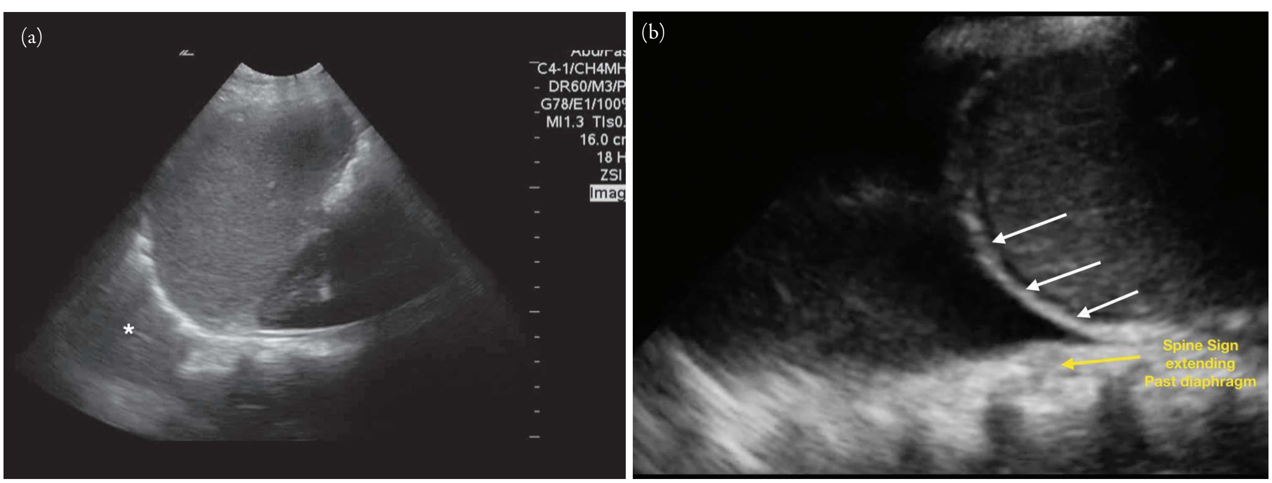

Figure 5.21 (a) **Mirror image artifact (*).** (b) **Spine sign (yellow arrow) with extension past the diaphragm (white arrows).**

Lobo V, Weingrow D, Perera P, Williams SR, Gharahbaghian L. Thoracic ultrasonography. *Crit Care Clin*. 2014;30(1):93–117, v–vi. doi:10.1016/j.ccc.2013.08.002.

Keywords/Tags: Lung, effusion, mirror, spine, sign, artifact

20. EXPLANATION

A. Pneumonia. Pneumonia is most likely to be present in the posterolateral aspect of the lung. This increase in the density of the lung parenchyma often reaches a level where the ultrasound beam can pass through the tissue, reflect off the thoracic vertebral bodies, and return to the transducer. The ultrasound in this case shows a positive spine sign (spine extends above diaphragm) with hepatization of the lung parenchyma, indicating a consolidation/pneumonia (Figure 5.13, Video 5.12). Asthma and COPD exacerbations do not generally cause a positive spine sign unless significant atelectasis is present. Pulmonary fibrosis can generate subpleural nodules and B-lines but does not usually cause a positive spine sign unless significant atelectasis is present.

Learning Points: A positive spine sign is generated any time the lower thorax is not completely filled with air such as with pleural effusion or pneumonia with consolidation.

REFERENCES

Durant A, Nagdev A. Ultrasound detection of lung hepatization. *West J Emerg Med*. 2010;11(4):322–323.
Nelson M, Stankard B, Greco J, Okumura Y. Point of care ultrasound diagnosis of empyema. *J Emerg Med*. 2016;51(2):140–143. doi:10.1016/j.jemermed.2016.05.023.

Keywords/Tags: Lung, pneumonia, consolidation, spine, sign

21. EXPLANATION

C. Length of the pleural effusion in the craniocaudal orientation and multiplied by the cross-sectional area at the widest portion of the effusion. While many methods have been described to quantify the size of a pleural effusion, probably the most accurate method is the Remerand method, which is described here (Figure 5.22a). This method was found to correlate well with the fluid drained on thoracentesis and the fluid measured by CT. A less accurate but possibly simpler method is called the Balik method, and it involves measuring the maximal effusion thickness between the diaphragm and base of lung in a supine patient (Figure 5.22b) and multiplying that number by 20. A supine chest X-ray requires as much as 500 mL of fluid to accumulate before it is reliably detectable, and an upright may need as much as 175 mL of fluid to accumulate before it is reliably detectable (Eibenberger, 1994).

Learning Points: The volume of a pleural effusion is best measured by the Remerand method.

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Ibitoye BO, Idowu BM, Ogunrombi AB, Afolabi BI. Ultrasonographic quantification of pleural effusion: comparison of four formulae. *Ultrasonography* (Seoul, Korea). 2018;37(3):254–260.
Remérand F, Dellamonica J, Mao Z, et al. Multiplane ultrasound approach to quantify pleural effusion at the bedside. *Intensive Care Med*. 2010;36(4):656–664. doi:10.1007/s00134-010-1769-9

Keywords/Tags: Lung, pleural effusion

22. EXPLANATION

D. A way to describe exudative pleural effusions. This finding describes the presence of small echogenic particles that can sometimes be seen floating within pleural effusions. The dynamic floating of the particles is known as "the plankton sign," which is the dynamic equivalent of the "hematocrit sign" that is seen in static images (Figure 5.23, Video 5.21). Both the plankton sign and hematocrit sign are indicative of an exudative effusion. Furthermore, the plankton sign or hematocrit sign in a patient with a history of cancer is highly predictive of a malignant pleural effusion (Chian, 2004). Transudative effusions are pleural effusions without echogenic particles within them. A-lines are formed when a uniform layer of air is seen at 90 degrees to the ultrasound beam. B-lines are generated when air and fluid are in close proximity to each other, such as what is seen in cardiogenic pulmonary edema.

Learning Points: The plankton sign describes echogenic particles floating within a pleural effusion and suggests an exudative process.

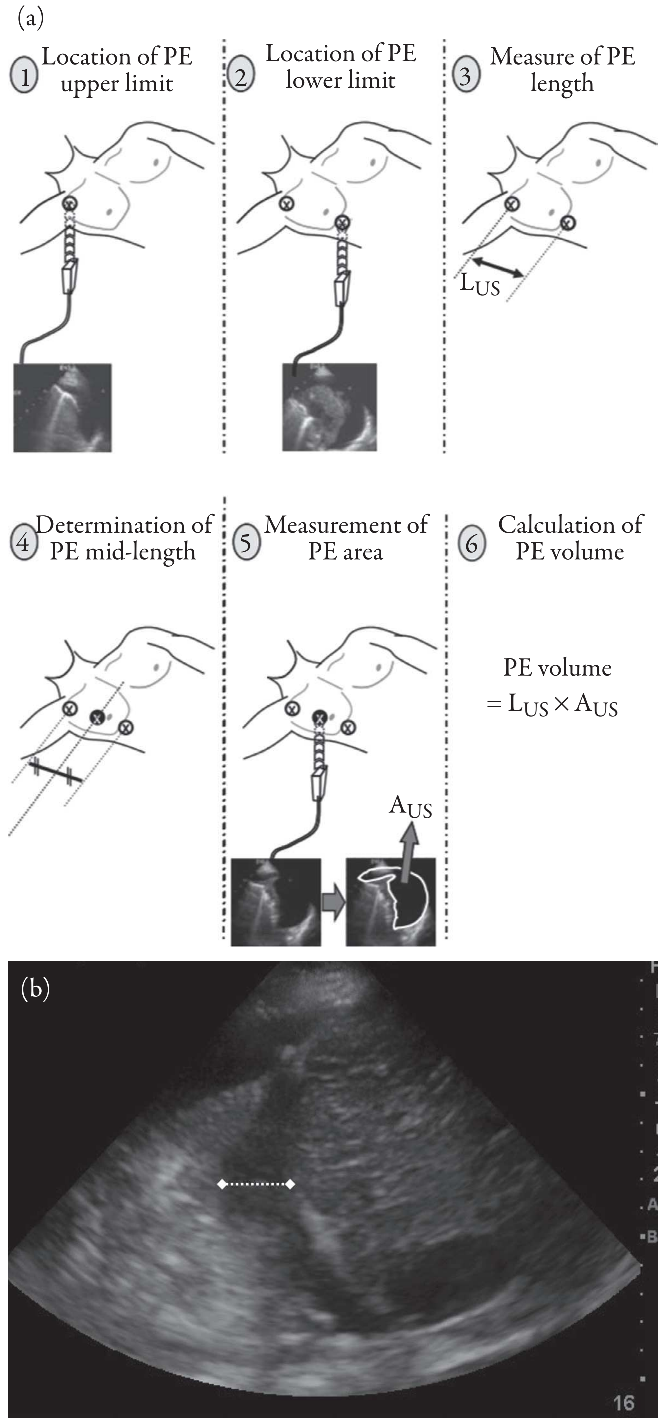

Figure 5.22 **Remérand method for quantifying pleural effusion volume.** The upper (1) and lower (2) paravertebral intercostal spaces where a pleural effusion (PE) is detected are drawn on the patient's skin. (3) The PE paravertebral length (LUS) is measured between these two points (in cm). (4) The middle of the PE height was located. At this point, the probe is applied to the skin in transverse plane, at end-expiration, as posterior as possible. (5) The cross-sectional area at mid-length (AUS) is measured in cm2. (6) Ultrasound PE volume (in ml) is calculated by multiplying LUS by AUS. Adapted from Figure 2 pf Remérand F, Dellamonica J, Mao Z, et al. Multiplane ultrasound approach to quantify pleural effusion at the bedside. *Intensive Care Med.* 2010;36(4):656–664. doi:10.1007/s00134-010-1769-9. (b) **Where to measure distance between visceral and parietal pleura for Balik method of quantifying pleural effusion volume.**

Figure 5.23 **Hematocrit sign showing echogenic material in the pleural space.**

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Keywords/Tags: Lung, pleural effusion, transudate, plankton, exudate, A-line, B-line

6.

AORTA ULTRASOUND

Zachary Soucy, Cecily Reynolds, Nicholas Weinberg, and David Haughey

QUESTIONS

1. A 66-year-old male presents to the emergency department (ED) with 5 hours of left flank pain that he describes as feeling like his prior "kidney stone." He denies dysuria, hematuria, fever, or chills. He has no other subjective complaints. His medical history is otherwise significant for a 40-pack/year smoking history, hypertension, diabetes mellitus, and 2 prior episodes of ureterolithiasis. He takes no medications. He is afebrile, his blood pressure is 84/52, his heart rate is 105, and a physical exam demonstrates a mildly diaphoretic obese male with no abdominal pain to deep palpation and mild flank discomfort to percussion. Which of the following is the most appropriate next step?

A. Urinalysis
B. Computed tomography (CT) urogram
C. CT abdomen/pelvis with intravenous (IV) contrast
D. Abdominal ultrasound

2. A 67-year-old male with hypertension, coronary artery disease (CAD), and active tobacco use presents with 2 hours of diffuse abdominal pain. His initial vital signs are temperature 37.2°C, heart rate 110, blood pressure 104/56. While in the ED, he suddenly suffers a pulseless electrical activity (PEA) cardiac arrest. As cardiopulmonary resuscitation (CPR) is initiated, the cardiac (Figure 6.1a, Video 6.1), inferior vena cava (IVC) (Figure 6.1b, Video 6.2), and aorta (Figure 6.1c) ultrasound images are obtained. Which of the following scenarios is most likely?

A. Obstructive shock, pulmonary embolism
B. Distributive shock, sepsis
C. Hypovolemic shock, ruptured AAA
D. Cardiogenic shock, ST-segment elevation myocardial infarction (STEMI)

3. Of the following, which are appropriate techniques to optimize visualization of the abdominal aorta?

A. Begin the exam with sufficient depth (sometimes up to 30 cm) and adjust as necessary.
B. Use color flow Doppler.
C. Apply continuous gentle compression.
D. All of the above.

4. You are unable to obtain adequate views of the aorta with the patient in the supine and left lateral decubitus positions. Which of the following is the next best step?

A. Have the patient take a deep breath.
B. Place the probe in the right anterior axillary line.
C. Place the probe in the right posterior axillary line.
D. CT of the abdomen with IV contrast.

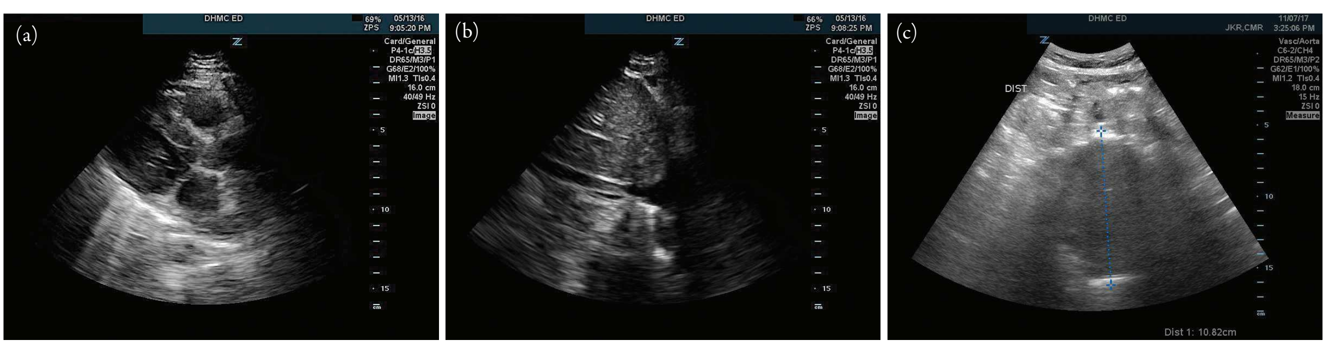

Figure 6.1

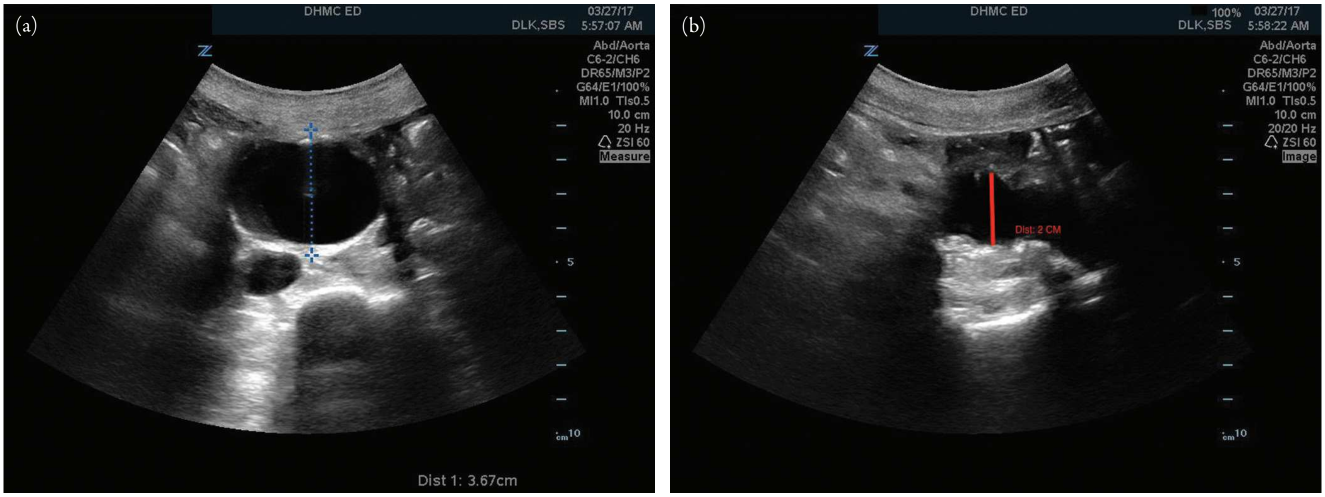

Figure 6.2

5. Of the following, which is *not* a component of a standard ultrasound exam of the abdominal aorta?

A. Visualization of the proximal, middle, and distal portions (including the iliac bifurcation) of the aorta
B. Visualization of the aorta in the transverse and longitudinal view
C. Measurement of diameter (outer wall to outer wall) from the anterior-posterior and lateral-lateral walls
D. Visualization of the entire aorta from the xiphoid process to the distal iliac arteries, except for image artifact resulting from bowel gas or the umbilicus

6. Which of the following are ultrasound diagnostic criteria for an AAA?

A. Diameter >3.0 cm
B. Measurement in the transverse view
C. Measure diameter from outer wall to outer wall
D. All of the above

7. Which of the following describes the most common aortic aneurysm location and morphology?

A. Saccular, thoracoabdominal, suprarenal
B. Saccular, thoracoabdominal, infrarenal
C. Fusiform, abdominal, infrarenal
D. Fusiform, abdominal, suprarenal

8. A 66-year-old male with past medical history significant for tobacco abuse, chronic kidney disease, hypertension, iodinated contrast allergy, and chronic low-back pain presents with approximately 6 hours of aching lumbar back pain radiating into the bilateral flanks. He insists that the pain is "different" than his typical back pain. He denies any urinary symptoms. He appears uncomfortable; his blood pressure is 160/80 and his heart rate is 90. He has mild tenderness to palpation of the paraspinal musculature. No costovertebral angle tenderness is present. His abdomen is scaphoid and no palpable masses are present. What is the next best course of action?

A. CT scan of the abdomen and pelvis, with IV contrast
B. Magnetic resonance imaging (MRI) of the lumbar spine
C. Point of Care Aortic Ultrasound
D. Urinalysis with reflux urine culture

9. What is the most likely explanation for the discrepancy in diameter measurements in Figure 6.2a and Figure 6.2b?

A. Cylinder tangent effect
B. Saccular aneurysm
C. Intraluminal thrombus
D. Misidentification of the IVC as the aorta

10. Which of the following represents correct placement of the measurement calipers to obtain the aortic diameter (Figure 6.3)?

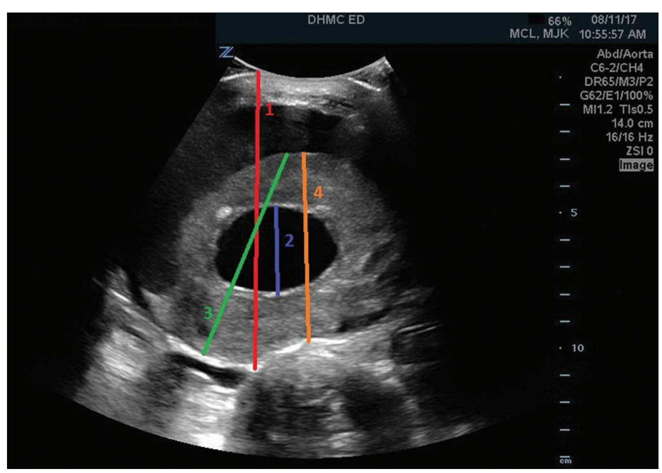

Figure 6.3

A. Measurement 1
B. Measurement 2
C. Measurement 3
D. Measurement 4

11. A 27-year-old male with a past medical history significant for Marfan's syndrome presents with sudden-onset tearing chest pain that radiates between the shoulder blades. He appears pale and diaphoretic; his blood pressure is 105/70 and his heart rate is 105. On cardiac auscultation, a 2/6 diastolic murmur is heard at the right upper sternal border. Which of the following images represents optimal probe placement (with the ultrasound machine in a standard cardiac setting) to evaluate for the most likely underlying etiology (the star in the images represents probe marker)?

A. Figure 6.4a, probe marker toward patient's left jaw
B. Figure 6.4b, probe marker toward sternum
C. Figure 6.4c, probe marker toward patient's right hip
D. Figure 6.4d, subxiphoid view

12. You wish to use ultrasound to evaluate an older man that has presented to your ED with a known AAA. Which of the following has the least inter-observer variability and is used for aneurysm surveillance and monitoring?

A. Peak wall stress
B. Anterior-posterior diameter
C. Medial-lateral diameter
D. 3D ultrasound volume

13. A 74-year-old male has just arrived by emergency medical services (EMS) with hypotension, syncope, and abdominal pain. While resuscitation is in progress you speak to the wife about her husband's medical history, asking if he has a known AAA. She replies that he was seen a few months ago for possible diverticulitis and she believes they were told the rest of the CT scan was normal. She becomes increasingly upset when you tell her you believe her husband possibly may have a ruptured AAA. Considering this situation, which of the following are true?

A. A previous recent CT or ultrasound with a normal caliber aorta can reliably exclude AAA.
B. Incidental AAAs of 3–3.9 cm found on routine CT of the abdomen have a missed reporting rate of approximately 50%.

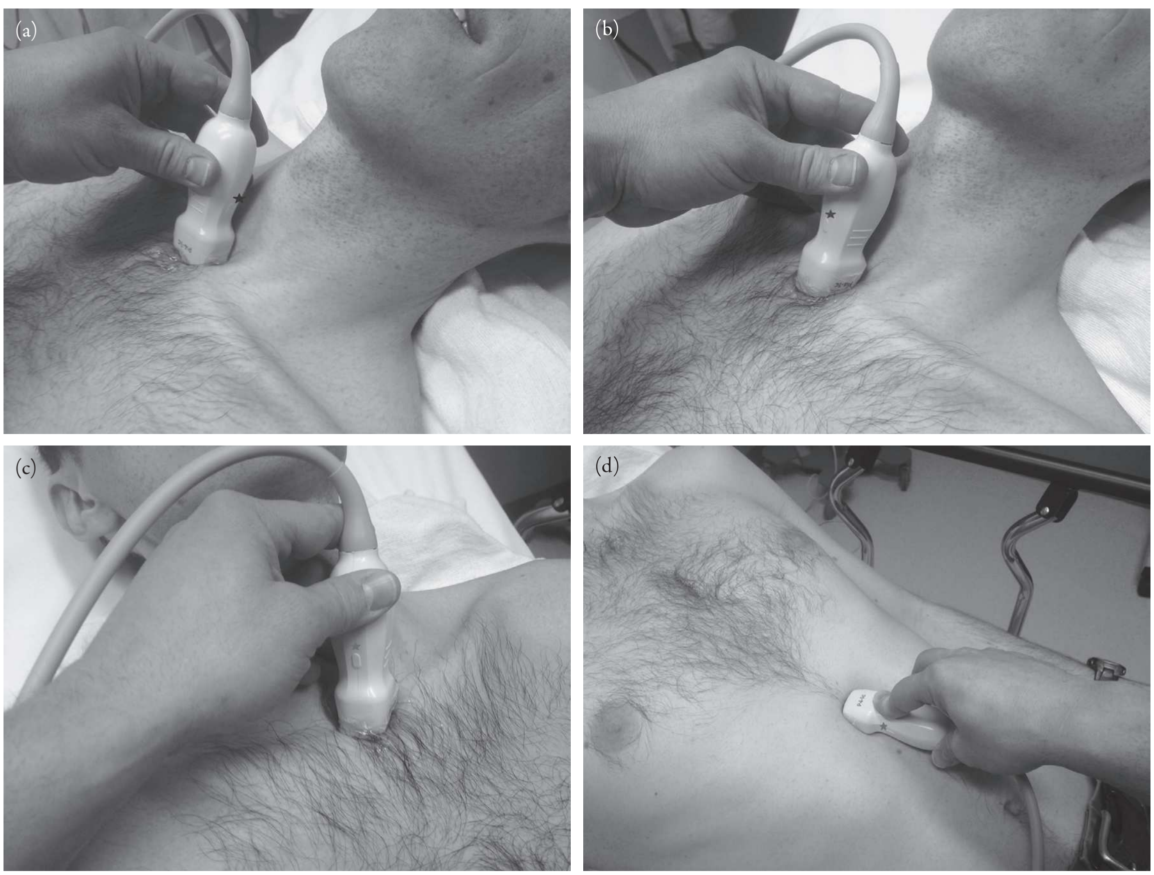

Figure 6.4

C. Up to two-thirds of people with incidental AAA diagnosed in an emergency or inpatient environment do not have that information communicated to the primary care physician (PCP) or the patient.
D. All of the above.

14. A 65-year-old male with a history of CAD, diabetes mellitus, and known peripheral vascular disease presents with tachycardia and abdominal pain. You wish to evaluate the aorta but are having difficulty due to body habitus and overlying bowel gas. Eventually you note a vascular structure in the abdomen on longitudinal view and note no fusiform aneurysmal dilation. Which characteristic(s) definitively confirms you are evaluating the aorta?

A. The structure is pulsating.
B. It does not appear to collapse when you apply pressure to the abdomen.
C. When you use pulsed-wave Doppler you note a triphasic waveform.
D. All of the above.

15. You are caring for a 78-year-old female with acute onset of abdominal pain and tachycardia. You suspect AAA and bedside ultrasound confirms your suspicion, with an aneurysm (Figure 6.5a, Video 6.3) that begins immediately distal from the obtained image (Figure 6.5b, Video 6.4). The patient becomes hypotensive and while continuing your resuscitation you contact vascular surgery. How would you describe the aneurysm?

A. Saccular aneurysm, ~5 cm diameter, distal aorta
B. Suprarenal fusiform aneurysm, ~5 cm diameter, involves celiac trunk
C. Fusiform aneurysm, ~5 cm diameter, possibly involving renal arteries
D. Isolated iliac artery aneurysm, ~5 cm diameter

16. A 57-year-old male with a history of tobacco use and known CAD presents to your ED with abdominal pain that has been intermittent for the past 3 days. He has a heart rate of 124 and his abdomen is soft. He is concerned because his father died from a ruptured AAA. A physical exam and ultrasound of the aorta are performed. Which of the findings can best help convince you and your patient that his pain and heart rate are *not* due to an aneurysm?

A. Bruising is visible on the patient's left flank and infrarenal aorta diameter is 4.5 cm
B. Serial measurements of the aorta with a maximal measurement of 2.8 cm, normal appearance on longitudinal view
C. No pulsating masses on abdominal exam, common iliac artery measurements bilaterally are 1.2 cm
D. Measurements of the aorta at the level of the SMA and just distal are 2.6 cm, poor visualization of distal aorta due to bowel gas

17. An ultrasound of the aorta is performed as part of the evaluation of a 75-year-old male with intermittent flank pain. You obtain a transverse image of the aorta, pictured in Figure 6.6. What is the significance of the identified vessel?

A. Suprarenal, or proximal, aortic aneurysms will rarely extend above this vessel.
B. Saccular aneurysms involve this vessel and have a poor prognosis.

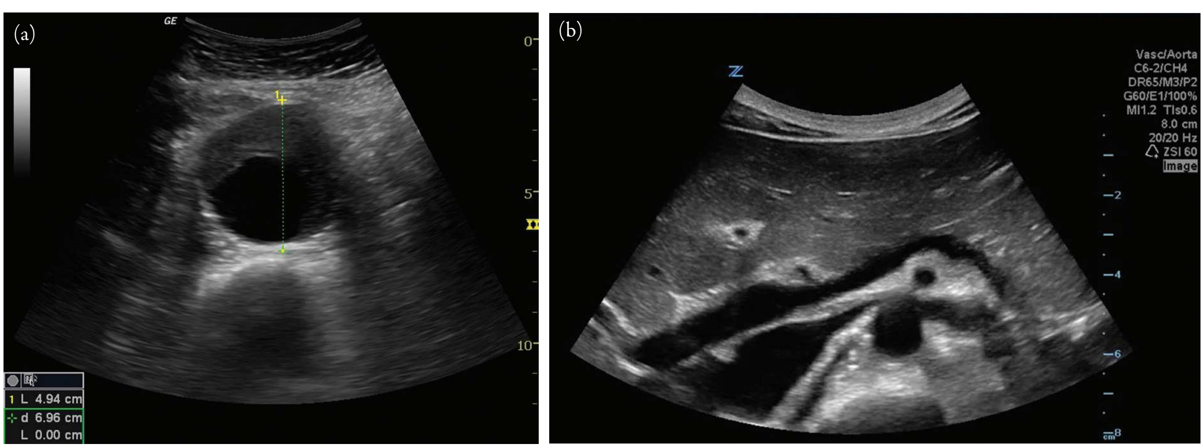

Figure 6.5

Figure 6.6

C. The vessel is located just proximal to the renal arteries. If an aneurysm is within 2 cm then the renal arteries are likely to be involved.
D. Aortic aneurysms at this level will occlude the splenic vein as it expands.

18. A 65-year-old homeless male intravenous (IV) drug user is brought in by ambulance after complaining of severe back pain. His vital signs are notable for hypotension, tachycardia, and fever. As part of his evaluation, a RUSH exam is performed, with findings of a hyperdynamic heart, no evidence of pleural or pericardial effusion, a collapsing IVC, and a localized, eccentric outpouching of the abdominal aortic wall. Which of the following statements is true?

A. Perioperative mortality is 15% to 20%.
B. Complications include aortoenteric fistulas and development of periaortic infections.
C. In the pre-antibiotic era, the majority of these aneurysms were due to seeding from endocarditis.
D. All of the above.

19. Regarding abdominal aortic ultrasound, which finding is most concerning for increased rupture risk?

A. Aneurysm size of 4.5 cm
B. Presence of atherosclerotic plaque and calcification on the aortic wall
C. Fissures within the intraluminal thrombus
D. Narrow aortic lumen due to presence of intraluminal thrombus

20. A 68-year-old male presents with cough to the ED. He is currently being evaluated for pneumonia, is hemodynamically stable, and is overall well appearing. While waiting for his results he agrees to be a model for your educational ultrasound rounds. The image in Figure 6.7 and Video 6.5 is obtained of his aorta. On further questioning, he has no abdominal pain, no flank pain, and no back pain. What is the next best step for the patient?

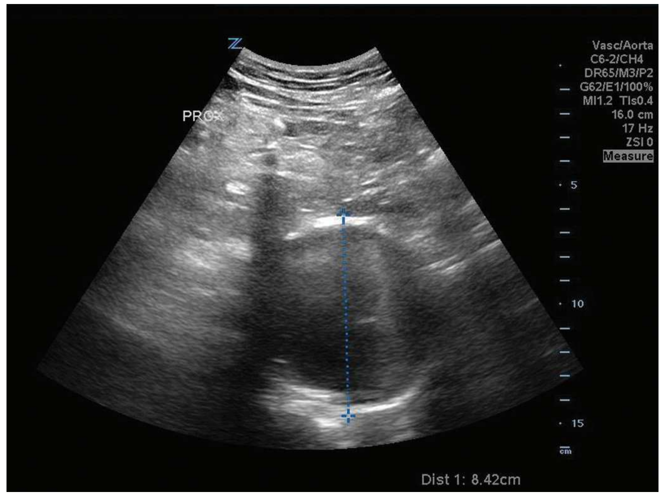

Figure 6.7

A. Prompt referral to vascular surgery for further evaluation as an outpatient
B. CT angiography of the aorta and vascular surgery consult
C. Begin steroids to help control periaortic inflammation, refer to vascular surgery as an outpatient
D. Begin immediate resuscitation, request uncrossmatched blood, call vascular surgery for an emergent evaluation in the ED

21. A 74-year-old female with history of hypertension, peripheral vascular disease, and tobacco use presents with left flank pain. Her husband had a kidney stone 2 years ago and she feels her symptoms are similar. She is hemodynamically stable; her abdomen is soft with some tenderness with deep palpation in left upper and lower quadrants, and bedside ultrasound shows the image in Figure 6.8 and Video 6.6. Urinalysis is negative for microscopic hematuria. What is your next step in management?

Figure 6.8

A. Symptomatic care and discharge home with outpatient urology follow-up
B. Noncontrast CT scan of the abdomen for further evaluation of the hydronephrosis
C. Bedside ultrasound to evaluate the aorta
D. Consult to urology

22. An 82-year-old female presents with diffuse abdominal pain. An ultrasound of the aorta is performed as part of her evaluation, and diameter is measured at 5.5 cm. As she is hemodynamically stable, a contrast enhanced CT scan is obtained to further evaluate the aorta and to rule out leak or rupture. She does have an aortic aneurysm, but CT measures it at 4 cm. What best explains the discrepancy between the ultrasound and CT measurements?

A. This is an example of the cylinder tangent effect leading to an erroneous measurement on ultrasound.
B. The bedside ultrasound was performed while the patient had head of bed elevation of 30 degrees; the CT scan was performed while the patient was lying flat.
C. The transverse diameter was not measured perpendicular to the long axis of the aorta on the ultrasound images.
D. Presence of thrombus led to an erroneous ultrasound measurement.

23. You obtain a transverse view of the distal aorta on a 73-year-old male with abdominal pain. There are multiple anechoic/hypoechoic structures, and you are unsure which structure to measure. What can you do to increase your confidence that you are evaluating the aorta?

A. Apply pressure to assess for vessel collapsibility.
B. Increase depth to look for landmarks to help identify visible structures.
C. Increase frequency for better image resolution and a cleaner image.
D. Apply color Doppler to assess for flow.

24. A 64-year-old male presents to your ED unresponsive. His wife tells you that he had sudden onset lower back pain followed by syncope. On physical exam his blood pressure is 64/40; his Glasgow Coma Scale is 6; and his skin is pale, cool, and clammy. You place the ultrasound probe over his abdomen and see a 6 cm AAA without intra-abdominal free fluid. After standard bedside resuscitation efforts, your next step in the management of this patient is to

A. Order CT angiogram of the patient's abdomen.
B. Consult vascular surgery for emergent surgery.
C. Order traditional angiogram.
D. Order formal ultrasound by radiology.

25. A 72-year-old female presents to your ED with abdominal pain and hypotension. A ruptured AAA is on your differential. You conduct a bedside focused assessment with sonography for trauma (FAST) exam, which is negative. With regard to whether it is clinically acceptable to infer that the patient's hypotension is from a cause other than a ruptured AAA given the negative FAST study, which is the correct statement?

A. AAAs typically rupture intraperitoneal with high volume free fluid.
B. The FAST is sensitive for low-volume intraperitoneal free fluid from a ruptured AAA.
C. FAST can adequately assess for retroperitoneal free fluid but not intraperitoneal free fluid.
D. AAAs are unlikely to rupture intraperitoneal.

26. A 72-year-old man presents with left lower quadrant abdominal pain. You conduct a bedside ultrasound exam of his abdomen which reveals a 3.8 cm aorta. You order a CT angiogram of the patient's abdomen, which demonstrates uncomplicated diverticulitis and confirms a 3.8 cm AAA without any evidence of rupture or extravasation. You determine that his diverticulitis can be managed as an outpatient. Your next course of action regarding the AAA is:

A. Discharge with no follow-up.
B. STAT vascular surgery consultation for emergent repair.
C. Outpatient vascular surgery referral for urgent outpatient repair in the next 7 days.
D. Outpatient vascular surgery referral for nonemergent follow-up.

27. You are conducting a bedside ultrasound study of the aorta in an obese patient and you see a vessel that you believe might be the aorta. Which would be the best modality to reliably differentiate the aorta from the IVC?

A. M-mode
B. Power Doppler
C. Pulsed wave Doppler
D. Color Doppler

28. You are attempting to identify the infrarenal aorta on bedside ultrasound. Which adjustment to the image shown in Figure 6.9 and Video 6.7 will best assist you in definitively identifying that the vessel imaged is the aorta?

Figure 6.9

A. Increase the gain.
B. Decrease the gain.
C. Increase the depth.
D. Decrease the depth.

29. A 72-year-old patient presents with sudden onset groin pain. His skin is cool and clammy; he appears unwell and is hypotensive. You are concerned about an AAA and ultrasound his abdomen and discover the image just distal to the aortic bifurcation (see Figure 6.10 and Video 6.8). What is the upper limit of normal for this structure in a woman?

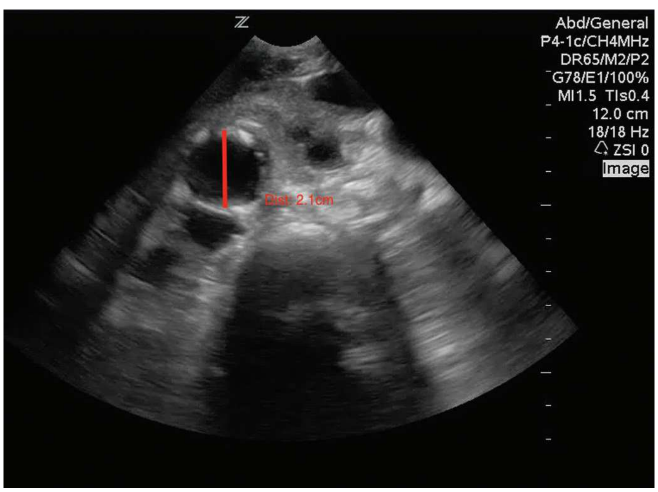

Figure 6.10

A. 0.5 cm
B. 1.5 cm
C. 2.5 cm
D. 4.5 cm

30. A 55-year-old woman with a history of hypertension, hyperlipidemia, and 60-pack years of smoking presents to your ED with acute bilateral leg, buttock and abdominal pain, as well as numbness and weakness of the lower extremities bilaterally. You notice that her lower extremities are cool and mottled with minimal monophasic Doppler signals bilaterally without palpable pulses; upper extremity pulses are normal. As she complains of abdominal discomfort, you place the ultrasound probe over her abdomen and see the image in Figure 6.11 and Video 6.9. Your next course of action is to

Figure 6.11

A. Initiate immediate blood pressure and rate control and consult vascular surgery for acute aortic dissection.
B. Begin blood transfusion and consult vascular surgery for AAA rupture.
C. Consult vascular surgery, begin anticoagulation if no contraindications, and order CT angiography (CTA) of the abdomen with run-offs into the lower extremities to evaluate for complete aortic occlusion.
D. Order formal bilateral lower extremity Doppler ultrasound and consult vascular surgery.

31. A 45-year-old otherwise healthy hemodynamically stable male presents with sharp, sudden-onset chest and abdominal pain that radiates to the back. You are concerned about acute aortic dissection as a cause of his symptoms. After obtaining standard transthoracic and transabdominal views of the aorta at the bedside, you see no evidence of dissection. Given these findings and his relatively low pretest probability for aortic dissection, what would be the most appropriate next step in management?

A. No further workup is necessary as you have ruled out aortic dissection.
B. Order a STAT bedside TEE.
C. Order a formal TTE.
D. Order CT angiogram of the chest, abdomen, and pelvis.

32. A 48-year-old male with a history of Marfan syndrome presents with sudden-onset tearing chest and neck pain. He is otherwise well appearing and hemodynamically stable. You have a high suspicion for acute aortic dissection. You are trying to decide whether to screen him with bedside thoracic and abdominal ultrasound prior to advanced imaging or instead go directly to advanced imaging. Which of the following statements is most correct?

A. The patient should receive bedside ultrasound without advanced imaging.
B. The patient should receive screening bedside ultrasound prior to advanced imaging while waiting for advanced imaging if it is not immediately available.
C. The patient should receive only advanced imaging without bedside screening ultrasound.
D. The patient should receive advanced imaging only if the screening bedside ultrasound is abnormal.

33. The patient from the previous question suddenly develops ripping chest pain in the ED. He is obtunded with a blood pressure of 63/40. What would be the preferred modality to definitively evaluate the patient for acute aortic dissection?

A. Bedside TTE
B. Bedside TEE
C. CTA
D. MRA

34. A 54-year-old male patient with a long history of poorly controlled hypertension presents with sudden-onset tearing chest pain radiating between the shoulder blades, as well as abdominal pain. The patient has a blood pressure of 215/176, heart rate of 136, and appears ill. He also has a diminished pulse in the right upper extremity compared to the left. You measure the structure within the red circle in Figure 6.12. What measurement is the upper limit of normal for this structure?

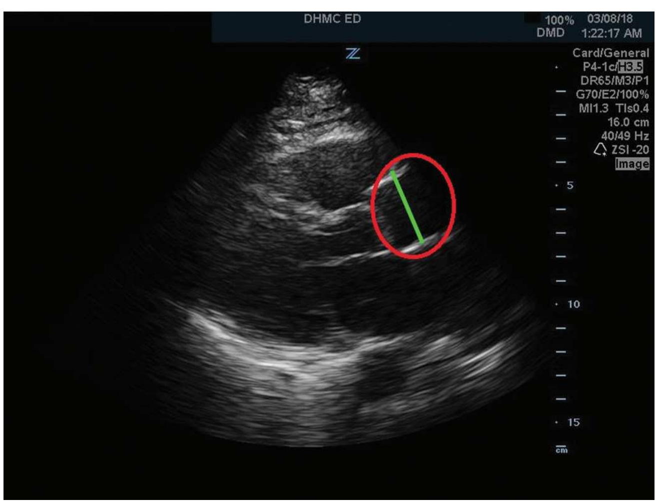

Figure 6.12

A. 2 cm
B. 3 cm
C. 4 cm
D. 5 cm

35. A 68-year-old male patient presents to the ED with tearing chest pain radiating to his back. A bedside transthoracic echocardiogram is performed and a parasternal long axis view is obtained (see Figure 6.13). Which of the statements best describes the utility of the particular finding (arrow) in making the diagnosis?

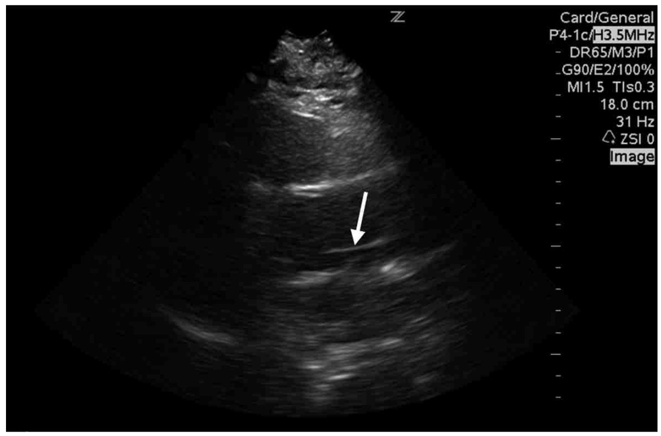

Figure 6.13

A. Neither sensitive nor specific
B. Sensitive but not specific
C. Specific but not sensitive
D. Highly sensitive and specific

36. EMS brings in an 80-year-old male with altered mental status to your ED. The patient's blood pressure is 82/50 and heart rate is 107. He is diaphoretic, tachypneic, altered, and complaining of pain all over. The family is at the bedside and states he has "everything wrong," including multiple heart issues and surgeries. You begin your resuscitation and decide to use ultrasound. You perform focused cardiac, aorta, pulmonary, and abdominal ultrasounds, which reveal a 5.6 cm AAA. Which acronym best describes the ultrasound approach utilized to evaluate the patient?

A. EFAST
B. FOCUS
C. HI-MAP
D. TAPSE

37. You are performing an ultrasound on a critically ill mildly obese patient (Figure 6.14, Video 6.10). Images

Figure 6.14

are suboptimal to make the diagnosis in the far field. In reference to this study, what technical adjustment can you perform to improve image quality?

A. Decrease frequency
B. Increase depth
C. Increase pulse repetition frequency
D. Decrease wavelength

38. A 77-year-old male presents to your ED with 3 weeks of increasing abdominal pain and 2 days of transient rectal bleeding. The patient denies fevers, chills, or postprandial pain. He notes diarrhea with 3 episodes of bright red blood mixed in. He has a history notable for diverticulitis, AAA with repair, CAD, and gastroesophageal reflux disease. You perform an abdominal ultrasound and obtain the image in Figure 6.15. What pathologic process do you suspect?

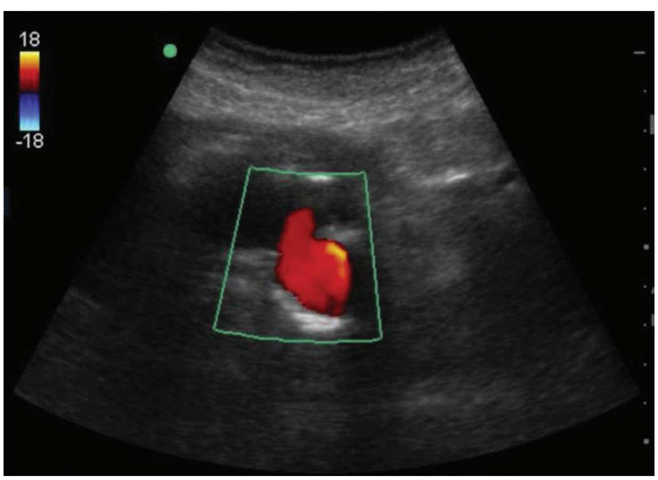

Figure 6.15

A. Aortoenteric fistula
B. Diverticulitis
C. Abdominal abscess
D. Crohn's disease

39. A 67-year-old male with a history of endovascular aortic aneurysm repair and end-stage renal disease on hemodialysis presents to your ED with back pain for several days similar to the pain that led to his aortic stent placement. He is hemodynamically stable. Which is the most appropriate definitive imaging modality?

A. Radiology performed, aortic ultrasound with B-mode, color, and pulse wave Doppler
B. POCUS with B-mode, color, and pulsed-wave Doppler
C. CTA
D. MRA

40. A 75-year-old presents to an ED with abdominal pain. A moonlighting resident performs an abdominal ultrasound to evaluate for AAA (Figure 6.16). In addition to an enlarged abdominal aorta, what finding is demonstrated in the image indicated by the *?

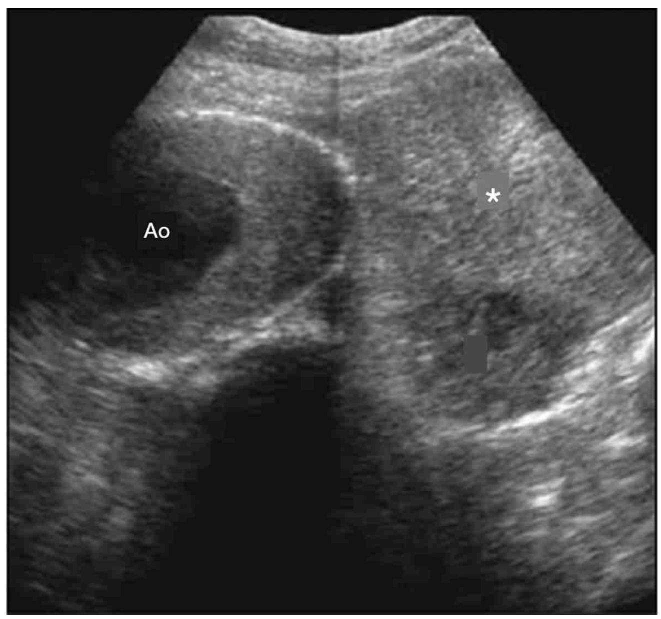

Figure 6.16

A. Endoleak
B. Retroperitoneal hemorrhage
C. Aortoenteric fistula
D. Intraluminal thrombosis

ANSWERS

1. EXPLANATION

D. Abdominal ultrasound. The classic triad of abdominal, back, or flank pain, hypotension; and a palpable abdominal mass is present in <25% of all patients who present with a ruptured abdominal aortic aneurysm (AAA; Lederle 1994). Although abdominal pain is the most common symptom (present in >80% of all patients), 60% of patients may report back or flank pain and 20% report groin pain (Lederle 1994; Marston 1992). Pain from an AAA can be referred to the abdomen, back, flank, groin, chest, thighs, shoulders, or buttocks (Lederle 1994).

A seminal study by Plummer et al. highlights the importance of immediate point-of-care ultrasound (POCUS) in patients with suspected ruptured AAA. Among 50 patients who presented with ruptured AAA, those who underwent immediate ultrasound had an average time to diagnosis of 5.4 minutes versus 83 minutes (for those who did not have immediate ultrasound). Furthermore, mortality among those who underwent immediate ultrasound was 40%, whereas mortality was 72% in those who did not undergo immediate ultrasound.

Renal ultrasound (although not listed as an answer choice) is also an appropriate next step given the patient's history of nephrolithiasis and his symptoms on presentation. Always interrogate the aorta in a patient with AAA risk factors, even if renal ultrasound demonstrates hydronephrosis, as AAA can cause ureteral obstruction.

Urinalysis should be ordered as routine workup but would not reveal an emergent cause for the hypotension. CT urogram and CT abdomen/pelvis are incorrect since patient is hypotensive and it would be unsafe to leave the ED.

Learning Points:

- Only a minority of patients with a ruptured AAA present with a "classic" symptoms.
- There is a significant mortality benefit when identifying AAA early in the course of a patient's ED evaluation using POCUS.

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Plummer D, Clinton J, Matthew B. Emergency department ultrasound improves time to diagnosis and survival in ruptured abdominal aortic aneurysm. *Acad Emerg Med*. 2018;5(5):417.

Keywords/Tags: AAA, abdominal aortic aneurysm

2. EXPLANATION

C. Hypovolemic shock, ruptured AAA. The ultrasound images are consistent with hypercontractile cardiac activity (Figure 6.1a, Video 6.1) (i.e., closely approximate ventricular walls at end-systole) and a flat, fully collapsed IVC (Figure 6.1b, Video 6.2). Given these findings, the aorta was interrogated via ultrasound and the image shown in Figure 6.1c was obtained, showing a large AAA. Cardiac arrest is not uncommon in patients with ruptured AAA. In one case series, cardiac arrest occurred in 24% of patients, and, of these, only 28% survived (Gloviczki 1992). If rupture occurs out of hospital, up to 62% of patients will die in the field and in-hospital mortality may be as high as 90% (Ernst 1993). The RUSH (rapid ultrasound in shock or hypotension) protocol (Perera 2010) for undifferentiated shock is a rapid ultrasound protocol looking at "the pump" (i.e., the heart), "the tank" (i.e., the IVC and lungs), and "the pipes" (i.e., the abdominal aorta and lower extremity deep veins). A hypercontractile heart can be seen in hypovolemic, obstructive, and distributive shock; conversely the heart is hypokinetic in cardiogenic shock. A flat, fully collapsed IVC further narrows the differential to hypovolemic and distributive shock. Given the absence of a clear infectious syndrome in the clinical vignette, distributive shock is unlikely. In the aforementioned clinical setting, cardiac arrest secondary to hypovolemic shock should prompt interrogation of the abdominal aorta for AAA. In the absence of AAA, completion of the full RUSH protocol will help determine if free fluid is accumulating in another body cavity as a cause of the patient's hypotension.

Learning Points: Utilize ultrasound during cardiac arrest/PEA to evaluate for multiple etiologies of shock.

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Perera P, Mailhot T, Riley D, Mandavia D. The RUSH exam: Rapid Ultrasound in SHock in the evaluation of the critically ill. *Emerg Med Clin North Am*. 2010;28(1):29–56–vii.

Keywords/Tags: AAA, abdominal aortic aneurysm, AAA rupture, abdominal aortic aneurysm rupture, cardiac arrest, undifferentiated hypotension, RUSH, rapid ultrasound for shock and hypotension

3. EXPLANATION

D. All of the above. Body habitus dictates a large portion of the ultrasound exam of the abdominal aorta. In patients with a large pannus, the initial depth setting may need to be as high as 30 cm to capture the vertebral bodies as a deep landmark for the aorta. A low-frequency curvilinear or phased array probe is used to acquire images. The curvilinear probe is typically preferred given its broad footprint. If present, the abdominal preset is used and when uncertainty exists as to whether the aorta is visualized, color Doppler can delineate vascular structures and help focus the exam. Decreasing frequency sacrifices resolution but may be required for visualization of deep structures such as the aorta. When excessive bowel gas is present, continuous gentle compression (sometimes up to 1–2 minutes) can aid with displacing bowel from between the probe and the aorta. Following that technique, patients can be put in the left or right lateral decubitus position to move air-filled bowel out of the ultrasound imaging field. The decubitus positions can also help displace a large pannus and thus minimize probe to aorta distance.

> **Learning Points:** Appropriate ultrasound probe selection and patient positioning are key to visualization of the abdominal aorta.

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Keywords/Tags: AAA, abdominal aortic aneurysm, knobology, patient positioning, obesity, body habitus, probe selection, color Doppler

4. EXPLANATION

B. Place the probe in the right anterior axillary line. In obese patients or those with excessive bowel gas (Figure 6.17a, Video 6.11), the coronal view should be used. Place the ultrasound probe over the ribs along the right anterior axillary line (Figure 6.17b) with the probe marker toward the patient's head. Using the liver as a sonographic acoustic window, maximize the depth until the IVC is seen in the near field (red arrow) and aorta (blue arrow) in the far field (Figure 6.17c, Video 6.12). Although this view is more limited, a longitudinal and transverse view can be obtained from the coronal plane. Visualization of vascular branches of the aorta may be difficult.

The gas-filled transverse colon often obscures the mid-aorta. At the anterior mid-line, fanning cephalad and caudad (with constant, gentle pressure) can overcome this obstacle. Most AAA's are infrarenal (i.e., occurring at or below the level of the renal arteries), where distal duodenum bowel gas can obscure imaging. The left periumbilical view (obtained at the aponeurosis formed by the rectus abdominis muscle as it meets the external oblique, internal oblique, and transversalis muscles) may improve image acquisition (Annals 2016).

If the aorta still cannot be visualized with ultrasound using these techniques, CT imaging is indicated in stable patients when suspicion for AAA is present but the abdominal aorta cannot be sonographically visualized. In one retrospective study, 8% of bedside ultrasounds in the ED yielded images in which >1/3 of the aorta was not visualized (Blaivas 2004). An aneurysm can be "hidden" in nonvisualized regions of the aorta. This is particularly important as the middle and distal portions of the aorta harbor most aneurysms and are more likely to be obscured by bowel gas.

In the supine position, deep inspiration lowers the liver and improves the hepatic sonographic window but is unlikely in isolation to overcome a large amount of bowel gas. The right posterior axillary view is not a typical ultrasound imaging window for the abdominal aorta.

> **Learning Points:**
> - Identify alternative imaging windows for visualization of the abdominal aorta in patients with excessive bowel gas or difficult body habitus.
> - If ultrasound imaging is nondiagnostic, CT imaging is indicated.

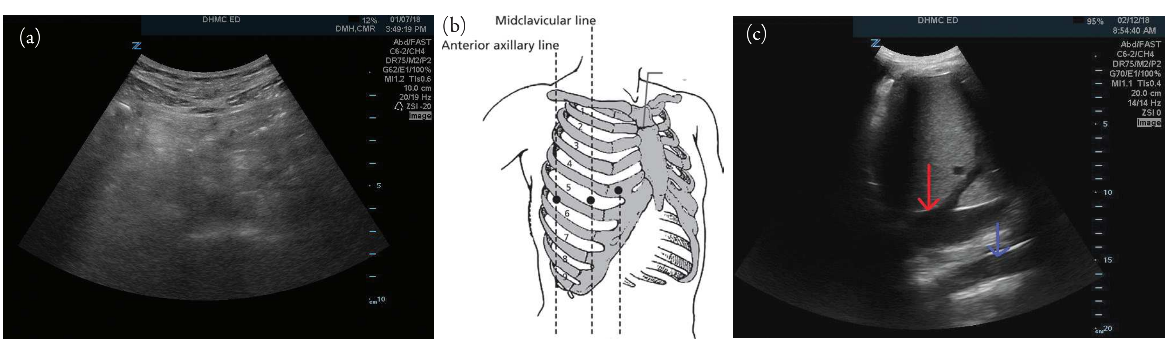

Figure 6.17 (a) **"Dirty shadowing" from scatter artifact.** (b) **Appropriate anatomic position of the right anterior axillary line.** Adapted from Figure 1 of Wung S-F. Discriminating between right coronary artery and circumflex artery occlusion by using a noninvasive 18-lead electrocardiogram. *Am J Crit Care.* 2007;16(1):63–71. (c) **View of inferior vena cava and aorta using the right anterior axillary view. Red arrow (IVC), Blue Arrow is Aorta.**

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Keywords/Tags: AAA, abdominal aortic aneurysm, ultrasound imaging windows, CT abdomen

5. EXPLANATION

D. Visualization of the entire aorta from the xiphoid process to the distal iliac arteries, except for image artifact resulting from bowel gas or the umbilicus. A complete ultrasound exam includes adequate imaging of the proximal, mid-, and distal aorta in both the transverse and longitudinal planes. The proximal view should be obtained at the level of the celiac trunk. The mid-view is obtained at the level of the superior mesenteric artery (SMA). The distal aorta view is obtained as the aorta bifurcates into the common iliac arteries. It is not necessary to view the entire aorta down to the distal iliac arteries (choice D).

The longitudinal view is obtained at the level of the xiphoid process. Start in the transverse view and rotate the probe 90 degrees clockwise so the marker points cephalad. The aorta can be distinguished from the IVC via the sniff test (the IVC will collapse while the aorta will remain patent) or by visualizing the aortic branches (i.e., celiac trunk/SMA).

The aortic diameter is measured at the proximal, mid-, and distal portions of the aorta in the transverse view from outer vessel wall to outer vessel wall. This is typically done in the anterior-posterior plane although lateral-lateral measurement should also be done as many AAAs have a larger diameter in this plane.

Learning Points: A complete ultrasound exam includes visualization of the proximal, mid and distal aorta (including aortic bifurcation into the common iliac arteries).

REFERENCE

Emergency Ultrasound Imaging Criteria Compendium. *Ann Emerg Med*. 2016;68(1):e11–e48.

Keywords/Tags: AAA, abdominal aortic aneurysm, ideal view, imaging windows, diameter measurement

6. EXPLANATION

D. All of the above. Aortic diameter >3.0 cm is consistent with an aortic aneurysm. Diameter measurement of the aorta should take place in the transverse view. Diameter is measured from the outermost portion of the vessel wall on one side to the outermost portion of the vessel wall on the opposite side. This should be done from the anterior to posterior wall, as ultrasound images tend to be better defined in this orientation. Although the diameter may be larger when measurements are taken from lateral wall to lateral wall, this can occur secondary to aortic tortuosity (rather than a true aneurysm). When measuring the aortic diameter in the longitudinal view, a common source of error is the cylinder tangent effect. If the ultrasound beam is not oriented along the true center of the aorta, oblique sections of aorta are visualized and the measured diameter will be an underestimation of the true diameter (Hirsch 2006; LeFevre 2014). A complete study will include the longitudinal view to confirm findings from the transverse view and better describe the aneurysm type.

Learning Points: An abdominal aortic aneurysm is diagnosed on ultrasound when the vessel diameter is >3.0 cm from anterior to posterior outer wall to outer wall in the transverse plane.

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LeFevre ML. Screening for abdominal aortic aneurysm: U.S. Preventive Services Task Force Recommendation Statement. *Ann Intern Med*. 2014;161(4):281–290.

Keywords/Tags: AAA, abdominal aortic aneurysm, diagnostic criteria, cylinder tangent effect, abdominal aorta diameter

7. EXPLANATION

C. Fusiform, abdominal, infrarenal. In general, fusiform aneurysms (uniform dilatation of the entire blood vessel wall) are far more common than saccular aneurysms (isolated outpouching of a single segment of the blood vessel wall). This is an example of a fusiform AAA (Figure 6.18, Video 6.13). At one institution, less than 1% of all surgically treated aortic aneurysms had saccular morphology. Saccular aneurysms most typically occur as a mycotic aneurysm or secondary to a penetrating aortic ulcer (Taylor 1999). Thoracoabdominal aneurysms are large, continuous aneurysms that involve the thoracic aorta, abdominal aorta, and major branches of the abdominal aorta (e.g., celiac trunk, SMA, renal arteries). Overall, thoracoabdominal aneurysms are quite rare, occurring in ~2% of all patients (Bhatt 2007). The majority of AAAs occur below the level of the

Figure 6.18 **Fusiform abdominal aortic aneurysm with intramural thrombus.**

renal arteries (i.e., in the distal or infrarenal segment of the abdominal aorta).

Learning Points: The most common type of aortic aneurysm is fusiform and located distal to the level of the renal arteries.

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Bhatt S, Ghazale H, Dogra VS. Sonographic evaluation of the abdominal aorta. *Ultrasound Clinics*. 2007;2(3):437–453.

Taylor BV, Kalman PG. Saccular aortic aneurysms. *Ann Vasc Surg*. 1999;13(6):555–559.

Keywords/Tags: AAA location, AAA morphology, abdominal aortic aneurysm, thoracoabdominal aneurysm, saccular aneurysm, fusiform aneurysm, infrarenal aneurysm,

8. EXPLANATION

C. Point of Care Aortic Ultrasound. Do not delay an abdominal aortic ultrasound because of additional work-up in patients in whom an AAA is suspected. The timing of nonultrasound imaging (i.e., CT or MRI) during peak hours may result in unforeseen delays whereas POCUS ultrasound is immediately available. Furthermore, CT and MRI imaging have associated risks (i.e., ionizing radiation, exposure to IV contrast) not posed by ultrasound. This patient has relative contraindications to a CT with IV contrast, given his chronic kidney disease and prior contrast allergy. Although detection of a palpable abdominal mass corresponding with an AAA is limited in obese individuals, even patients with a normal body mass index infrequently have a palpable AAA. A study of over 300 patients by Rose et al. found that only 18% of patients presenting with a ruptured AAA had a palpable mass on exam. Furthermore, early POCUS in patients with a ruptured AAA has been shown to reduce mortality by as much as ~30% (Plummer 2018).

Learning Points: Do not delay ultrasound of the abdominal aorta when the diagnosis of AAA is suspected.

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Keywords/Tags: AAA, abdominal aortic aneurysm, physical exam

9. EXPLANATION

A. Cylinder tangent effect. For purposes of diameter measurement, the aorta approximates a cylinder. When measuring the diameter of a cylinder, care must be taken to measure across the true center of the cylinder. If measurements are taken at a point other than the true center of a cylinder, diameter may be underestimated. This error is termed the "cylinder tangent effect" (Figure 6.19). It is more likely in the longitudinal plane, where it is more difficult to tell if the ultrasound beam is oriented across the true center of the aorta. As such, the transverse plane is favored for diameter measurement. When the aorta appears as a circle in the transverse plane, the likelihood of off-center or oblique imaging

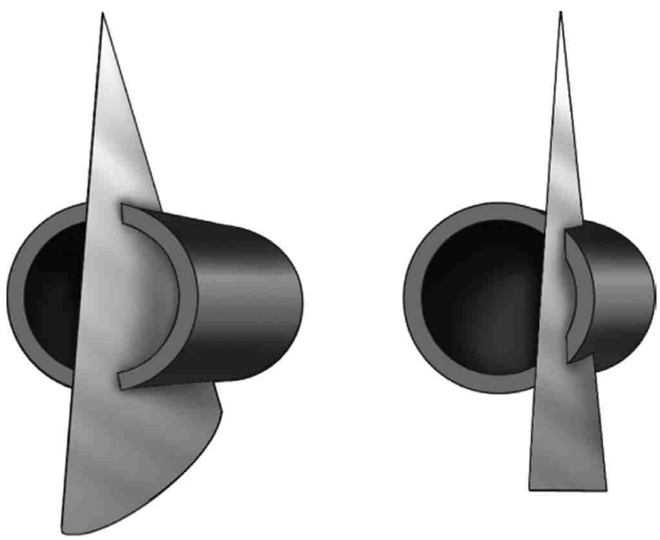

Figure 6.19 **Cylinder tangent effect.** Adapted from: Reardon R, Clinton M, Madore F, Cook T. Abdominal aortic aneurysm. In: Ma OJ, Mateer J, Reardon R, Joing S, eds. *Emergency Ultrasound*. 3rd ed. New York, NY: McGraw-Hill Education; 2014:225–245.

planes is minimized and the most accurate diameter measurement is obtained. Although a tortuous aorta was not listed as a possible answer choice, this can also lead to discrepancy in diameter measurements taken at different imaging planes, depending upon what portion of the tortuous aorta is captured. A saccular aneurysm would be apparent in the transverse view as a focal outpouching of the aorta. Intraluminal thrombus should be apparent as an echogenic region within the vessel lumen and can be made more apparent through manipulation of gain. When switching from a transverse to longitudinal view, the probe could inadvertently translate to the region directly above the IVC, possibly resulting in discrepancy of diameter measurement. However, compressibility, collapse with sniff, and spectral Doppler waveform can readily distinguish IVC from aorta if there is uncertainty.

Learning Points: Recognize cylinder tangent effect as a cause of inaccurate measurement of AAA.

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Bhatt S, Ghazale H, Dogra VS. Sonographic evaluation of the abdominal aorta. *Ultrasound Clinics*. 2007;2(3):437–453.

Reardon RF, Clinton ME, Madore F, Cook TP. Abdominal aortic aneurysm. In: Ma OJ, Mateer JR, Reardon RF, Joing SA, eds. *Ma & Mateer's Emergency Ultrasound*. 3rd ed. New York, NY: McGraw-Hill; 2014:225–246.

Keywords/Tags: AAA, abdominal aortic aneurysm, cylinder tangent effect, aneurysm diameter

10. EXPLANATION

A. Measurement 1. Measurement 1 appropriately measures the diameter from the outer wall to outer wall of the aorta. Measurements 2, 3, and 4 inappropriately include the thrombus in the measurement of aorta diameter. Intramural thrombus can lead to underestimation of the true diameter of the aorta. When it is unclear whether a clot is present, adjust the gain to maximize the contrast between thrombus and blood within the aorta, such that the blood becomes completely anechoic (black) and the thrombus becomes hypoechoic (dark grey). A chronic intramural thrombus can become calcified and be mistaken as bowel outside the aorta. Always measure from the outermost portion of the vessel walls and err on the conservative side when measuring the aortic diameter.

Learning Points: Measure the diameter of the abdominal aorta from outer wall to outer wall.

REFERENCES

Bhatt S, Ghazle H, Dogra V. Sonographic evaluation of the abdominal aorta. *Ultrasound Clinics*. 2007;2(3):437–453.

Keywords/Tags: AAA, abdominal aortic aneurysm, intramural thrombus, AAA diameter

11. EXPLANATION

A. Figure 6.4a, probe marker toward patient's left jaw. The correct position (in a cardiac setting) for the suprasternal view is with the probe marker toward the patient's left jaw. In most situations, transesophageal echocardiogram (TEE) or CT angiogram are the diagnostic modalities of choice to evaluate the thoracic aorta. Transthoracic echocardiography (TTE) has very low sensitivity for detection of thoracic aortic dissection, so it cannot be used to rule out this diagnosis. However, TTE findings of a dissection flap or aneurysm of the thoracic aorta at the sternal notch, suprasternal view, are relatively specific (Khandheria 1989). If the ultrasound is on an abdominal setting, optimal probe placement is at the sternal notch with the probe directed inferiorly into the mediastinum. The probe marker should be directed obliquely between the patient's right side and the anterior plane, as this orientation will allow the ultrasound beam to capture the aortic arch as it crosses from the right anterior mediastinum to the left posterior mediastinum. If the ultrasound is in a cardiac setting, probe placement differs. In this setting, the indicator is initially aimed toward the patient's trachea and rotated slightly clockwise toward the left jaw. This typically results in the probe indicator facing posterior and to the patients left, exactly opposite (180 degrees) from the indicator position when in the abdominal mode. In the suprasternal view, the ascending aorta (Figure 6.20, label 1), aortic arch, brachiocephalic artery (Figure 6.20, label 2), left common carotid artery (Figure 6.20, label 3), left subclavian artery (Figure 6.20, label 4) and descending aorta (Figure 6.20, label 5) can be visualized (Video

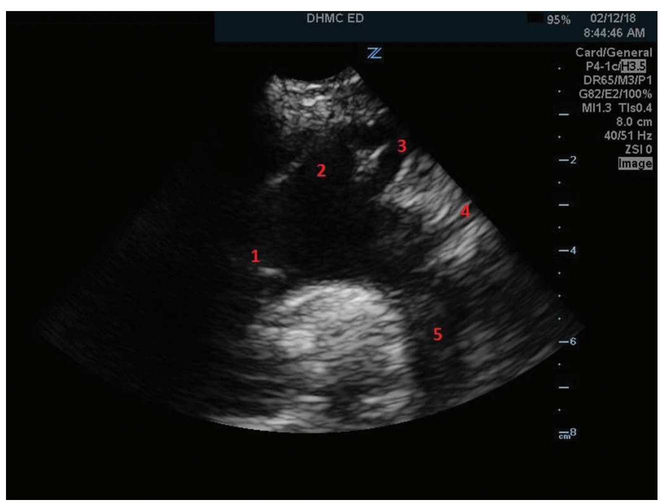

Figure 6.20 **Suprasternal view of aortic arch.** 1 = ascending aorta; 2 = brachiocephalic artery; 3 = left common carotid artery; 4 = left subclavian artery; 5 = descending aorta.

6.14). Placing a pillow under the patient's shoulders and having the neck fully extended improves image acquisition.

Learning Points: Recognize optimal probe placement for visualization of the thoracic aorta at the suprasternal notch.

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Keywords/Tags: AAA, abdominal aortic aneurysm, aortic regurgitation, thoracic aortic dissection, abdominal aortic dissection, aortic root dilatation, suprasternal view

12. EXPLANATION

B. Anterior-posterior diameter. AAA diameter is the best reproducible measurement to be used as a predictor of risk of rupture. Ultrasound performed in the ED by experienced providers has been shown to have a sensitivity and specificity of 100% and 98%, respectively, for detecting AAA by the anterior-posterior diameter. A systematic review of ED bedside ultrasonography for AAA, published in 2013, had a pooled sensitivity of 99% and specificity of 99% (Rubano 2013). Multiple studies have investigated inter- and intraobserver variation in measurement, finding that repeatability of maximum aortic diameter measurement was greater when measuring anterior-posterior diameter rather than the medial-lateral diameter. A variation of 5 mm between user measurements using ultrasound is generally regarded as clinically acceptable with most studies showing variability of 3–4 mm (Beales 2011). It is important to note that variability between users increases as aorta size increases (Kontopodis 2016). Peak wall stress is a CT-generated measurement of the highest wall stress within a AAA and has been suggested as a predictor of AAA rupture. Currently, ultrasound does not have the capability to assess biomechanical factors such as peak wall stress (Khosla 2014). 3D ultrasound is relatively new in AAA assessment and could have a role in future surveillance programs. 3D volume measurements are currently performed with CT software analysis and have a low inter-observer variation. Increased volume is associated with increased risk of rupture (Ghulam 2017).

Learning Points: Aortic diameter has the highest inter-observer reliability and is currently used for AAA surveillance.

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Khosla S, Morris DR, Moxon JV, Walker PJ, Gasser TC, Golledge J. Meta-analysis of peak wall stress in ruptured, symptomatic and intact abdominal aortic aneurysms. *Br J Surg.* 2014;101(11):1350–1357.

Kontopodis N, Lioudaki S, Pantidis D, Papadopoulos G, Georgakarakos E, Ioannou CV. Advances in determining abdominal aortic aneurysm size and growth. *World J Radiol*. 2016;8(2):148.

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Keywords/Tags: Abdominal aortic aneurysm, 3D ultrasound, peak wall stress, CT measurement of AAA

13. EXPLANATION

D. All of the above. Almost two-thirds of patients have lack of follow-up of radiology reports with incidental AAA findings (van Walraven 2011). One Canadian review found an independent association between detection of AAA on CT scans performed in EDs and inpatient setting and incomplete AAA monitoring. Only 29% of incidental AAAs detected as an inpatient were noted on the discharge summary, and only 15% were communicated to the family physician. Mean AAA size in that case series was 4 cm (van Walraven 2010). In another review of a hospital system using an advanced electronic record, 58% of patients had no documentation of aortic dilation in their medical record 3 months after CT scan had been performed, with 9% of these having AAA >5.5 cm (Gordon 2009). Another case series published by Zommorodi et al. in 2017 found that failure to report AAA appeared related to urgency of the CT scans: 77% AAA found on CT scans obtained urgently for other causes went unreported and 58% were unreported on routine scans. The same case review found that all AAA greater than 5 cm were reported; the least likely to be reported were those 3–3.9 cm in size. On the other hand, a retrospective study of subjects over the age of 65 presenting to an ED with complaints of abdominal pain found that a recent (<1 year) previously normal caliber aorta on CT or ultrasound could reliably exclude AAA as cause of the patient's current symptoms (Hahn 2016).

Learning Points:

- A majority of AAA diagnosed incidentally on imaging are not communicated to the patient or their PCP.
- Incidental findings of AAA should be communicated to the patient's PCP and should be detailed in the discharge instructions.

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Keywords/Tags: Incidental AAA, delay in communication

14. EXPLANATION

C. When you use pulsed-wave Doppler you note a triphasic waveform. When interrogating the aorta in longitudinal view, a common imaging error is to accidentally slide the probe, or sweep the plane of the ultrasound beam, to the right, leading to a long axis view of the IVC instead of the aorta. Common defining characteristics of the aorta are its pulsatile nature and lack of collapse. Unfortunately, in certain situations the IVC can appear pulsatile, usually due to its proximity to the aorta or to a hyperdynamic state and increased cardiac motion. The IVC is frequently compressible in those with a thin body habitus; however, in conditions associated with increased central venous pressures or right atrial pressures, such as congestive heart failure, severe pulmonary hypertension, and acute pulmonary embolus, or in obese patients, the IVC might not collapse with applied pressure to the abdominal wall (Lema 2017). Pulsed wave Doppler provides a measure of velocity over time, with velocity and direction on the Y-axis and time on the X-axis. Typically, the aorta has a triphasic waveform that is associated with normal arterial flow (Figure 6.21a, Video 6.15): forward flow in systole (S), reverse flow in mid-diastole (MD), forward flow in late diastole (LD) (Battaglia 2010). Various pathologic conditions may lead to a biphasic waveform. Doppler waveforms of the IVC (Figure 6.21b, Video 6.16), in contrast, show an initial shallow upward deflection with atrial contraction (A) and shallow downward deflections with ventricular systole (S) and diastole (D). Overall, aortic waveforms will have a steeper initial deflection and much higher velocities than those seen in venous Doppler wave forms (Bhatt 2007).

Learning Points: Without pulse wave doppler venous and arterial vasculature can be confused for each other based on size, wall thickness, and compressibility in pathologic states.

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Keywords/Tags: IVC, aorta, spectral Doppler

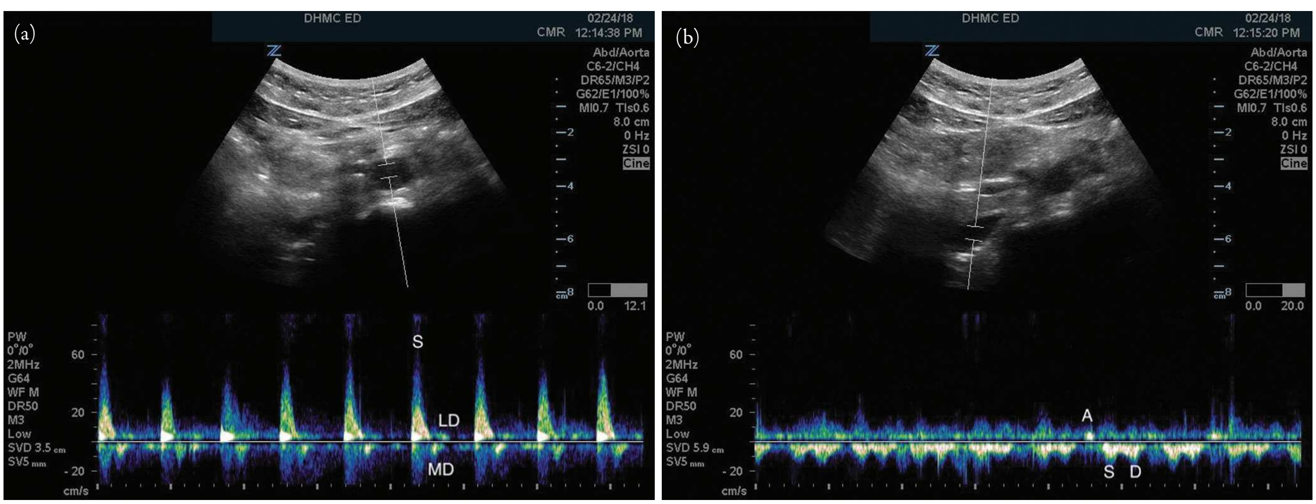

Figure 6.21 (a) **Pulsed-wave Doppler of the aorta.** Forward flow in systole (S), reverse flow in mid-diastole (MD), forward flow in late diastole (LD). (b) **Pulsed-wave Doppler of the inferior vena cava.** Initial shallow upward deflection with atrial contraction (A), and shallow downward deflections with ventricular systole (S) and diastole (D).

15. EXPLANATION

C. Fusiform aneurysm, ~5 cm diameter, possibly involving renal arteries. To properly evaluate and screen for AAA the full abdominal aorta must be interrogated (AIUM 2015). Knowledge of the vasculature and anatomy of the aorta and associated IVC helps identify the location of an aneurysm. Recognition of the celiac artery guarantees that investigation of the aorta is beginning high enough in the abdomen and also identifies the object being interrogated as the aorta (Bhatt 2007). On transverse view the celiac trunk appears "seagull" in shape: the body is the celiac artery; the common hepatic artery is the right wing; the left wing is the splenic artery (Figure 6.22a). The SMA is just proximal to the renal arteries; aneurysm proximity to the SMA increases suspicion that renal arteries are involved as in this case. Other vessels associated with the SMA visualized on transverse view include the splenic vein, passing over the SMA to become the portal vein on the patient's right, and the left renal vein passing between the aorta and SMA before joining the IVC (Figure 6.22b, Video 6.17). The inferior mesenteric artery is rarely visualized on ultrasound. Identification of the aortic bifurcation and the iliac arteries ensures that the abdominal aorta has been fully interrogated. To complete the exam, iliac artery measurements just distal to the bifurcation are recorded, and the IVC is interrogated for flow (AIUM 2015). Aneurysms are generally fusiform, appearing as a symmetric enlargement of the abdominal aorta. Saccular or eccentric aneurysms are unusual and are a localized out-pouching of the aortic wall (Bhatt 2007). The aneurysm in the image is a single vessel over the spine—this is consistent with the aorta, not the iliac arteries.

Learning Points: Knowing vasculature arising from the aorta is important for assuring accurate identification of vascular structures and landmarks for appropriate scanning technique.

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Keywords/Tags: Fusiform, saccular, AAA, iliac, infrarenal, celiac trunk, SMA, renal arteries

16. EXPLANATION

B. Serial measurements of the aorta with a maximal measurement of 2.8 cm, normal appearance on longitudinal view. An aneurysm of an arterial vessel is defined as a diameter of 1.5 cm or more from normal (Johnston 1991). The normal aorta tapers distally to approximately 1.5 cm, ending at the level of L4, at the umbilicus, where it divides into the iliac arteries. Understanding that the aorta tapers is important, as the supraceliac aorta can measure 2.7 cm; a supraceliac aorta diameter of 3 cm is not abnormal given the definition of an aneurysm (Table 6.1). The infrarenal aorta should not have an anterior-posterior diameter greater than 3 cm, and an aneurysm of the common iliac artery is present in diameters greater than 1.5 cm for women and 1.8 cm for men (Bacharach 2008). Luminal diameter does vary with age and sex, and young male and female patients without known atherosclerotic disease have infrarenal aortic diameters of about 2.3 cm and 1.9 cm, respectively. Physical exam is limited by

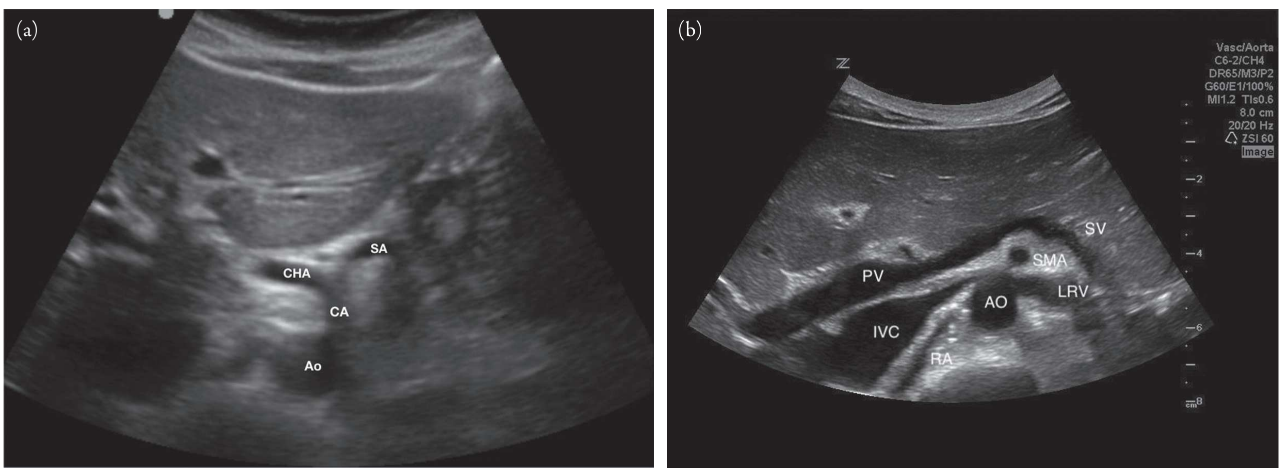

Figure 6.22 (a) **Seagull sign.** On transverse the view the celiac trunk appears "seagull" in shape: the body is the celiac artery (CA); the common hepatic artery (CHA) is the right wing; the left wing is the splenic artery (SA). (b) **Transverse view of aorta at level of superior mesenteric artery.** Portal vein (PV), aorta (Ao), splenic vein (SV), superior mesenteric artery (SMA), left renal vein (LRV), renal artery (RA), inferior vena cava (IVC).

Table 6.1. **MEAN DIAMETER (CM) FOR THE NORMAL AORTA IN 70-YEAR-OLD MEN AND WOMEN**

AORTA SEGMENT	MEN	WOMEN
Supraceliac	3.0	2.7
Suprarenal	2.8	2.7
Infrarenal	2.4	2.2
Bifurcation	2.3	2.0

Adapted from: Wanhainen A, Themudo R, Ahlström H, Lind L, Johansson L. Thoracic and abdominal aortic dimension in 70-year-old men and women—a population-based whole-body magnetic resonance imaging (MRI) study. *J Vasc Surg*. 2008;47(3):504–512.

body habitus and abdominal circumference. Detection of AAA is increased on physical exam by deep palpation of the abdomen to detect an abnormal widening of the aortic pulsation. Sensitivity increases with increased AAA diameter. The absence of a pulsating mass on abdominal exam does not rule out an AAA (Lederle 1999). Ecchymosis of the flanks, though rare, is indicative of retroperitoneal hematoma and, when present in a patient with family history of AAA as well as tachycardia and abdominal pain, should increase clinical suspicion for ruptured AAA (Epperla 2015).

Learning Points: Infraceliac aortic aneurism is defined as an anterior to posterior diameter >3 cm.

Iliac arteries are aneurismal at 1.5 cm for women and 1.8 cm for men.

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Keywords/Tags: Anterior-posterior diameter, aorta anatomy, physical exam

17. EXPLANATION

C. The vessel is located just proximal to the renal arteries. If an aneurysm is within 2 cm then the renal arteries are likely to be involved. The identified vessel is the SMA. This is the second of the major branches of the abdominal aorta, sitting about 2 cm distal to the celiac trunk and just proximal to the renal arteries. An aneurysm within 2 cm caudal of the SMA should increase suspicion that it involves the renal arteries (Bertino 2018). Suprarenal, or proximal, aneurysms are located above the renal arteries, which are just distal to the SMA. By anatomic location, suprarenal aneurysms will extend above the SMA. A long axis view of the aorta can be used to identify the SMA as it runs parallel to the aorta (Figure 6.23) Saccular aneurysms are a localized outpouching of the aortic wall and rarely localize to the SMA (Bhatt 2007) The splenic vein passes over the SMA to become the portal vein on the patient's right, thus aortic aneurysms at the level of the SMA will not occlude the splenic vein (Figure 6.22b, Video 6.17).The left renal vein passes between the aorta and SMA before joining the IVC. Infrarenal AAA is a rare cause of anterior nutcracker syndrome, due to compression of the left renal vein between the SMA and aorta with resulting renal pelvic congestion and renal venous hypertension (Lozuk 2014).

Figure 6.23 **Long axis view of aorta with celiac trunk and SMA.** Aorta (Ao), superior mesenteric artery (SMA).

Learning Points: Identify the SMA and its characteristics and understand its importance in relation to the renal arteries.

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Lozuk B, Tanaskovic S, Radak D, Babic S, Kovacevic V, Matic P. Infrarenal abdominal aorta aneurysm: a rare cause of anterior nutcracker syndrome with associated pelvic congestion. *Ann Vasc Surg*. 2014;28(1):263.

Keywords/Tags: AAA, SMA, saccular aneurysm, nutcracker syndrome

18. EXPLANATION

D. All of the above. A patient with a saccular aneurysm and fever of unknown origin should be presumed to have an infected aneurysm (Oderich 2001). This type of aneurysm is rare and is frequently associated with complicating factors of sepsis or rupture. One case review found that the patients themselves are often immunosuppressed with diabetes, chronic steroid use, or renal failure, and almost half had a recent infection, including endocarditis, pneumonia, and cholecystitis (Sekar 2010); see Table 6.2. Infected AAAs classically present with fever and abdominal or back pain, though they can also present as fever of unknown origin. Prior to the introduction of antibiotics, the majority of infected aneurysms were due to endocarditis (Sato 2012); see Table 6.3.

Complications include aortoenteric fistulas, multiple aneurysms, and periaortic infections with purulent collections associated with adjacent structures, including the IVC, the left renal vein, and the left kidney (Oderich 2001; Sekar 2010). There is a high perioperative mortality of 15% to 20%, and morbidity and mortality are frequently related to end-organ ischemia. In an individual with a history of IV drug use, one must presume an infected aneurysm, likely from bacteremic seeding to a previously existing aneurysm or atherosclerotic plaque. Rarely is there direct seeding of the aortic wall, though infected pseudoaneurysms can occur with IV drug abusers at other sites, including carotid or femoral arteries (Oderich 2001).

Learning Points:

- Define a saccular aneurysm and understand pathologies associated with this subtype when found in the abdominal aorta.
- Consider infected aneurysm in a patient with both a saccular aneurysm and fever of unknown origin.

Table 6.2. ETIOLOGY OF SACCULAR ANEURYSMS

- **Pseudo-aneurysm from trauma**
- **Iatrogenic (invasive monitoring, percutaneous access)**
- **IVDA stands for Intravenous drug abuse**
- **Self-inflicted (intravenous drug abusers)**
- **Enlarging penetrating ulcer**
- **Infection of arterial wall**
- **Vasculopathy**

Adapted from: Sekar N. Primary aortic infections and infected aneurysms. *Ann Vasc Dis*. 2010;3(1):24–27.

Table 6.3. SONOGRAPHIC FINDINGS CONCERNING FOR INFECTED ANEURYSM

- **Saccular or eccentric AAA**
- **Lack thrombus or atherosclerotic changes in the AAA**
- **Intramural air**
- **Periaortic inflammatory changes**
- **Periaortic lymphadenopathy**
- **Retroperitoneal abscess**

Note. AAA = abdominal aortic aneurysm.

Adapted from: Bhatt S, Ghazale H, Dogra VS. Sonographic evaluation of the abdominal aorta. *Ultrasound Clinics*. 2007;2(3):437–453.

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Sekar N. Primary aortic infections and infected aneurysms. *Ann Vasc Dis*. 2010;3(1):24–27.

Keywords/Tags: Mycotic aneurysm, saccular aneurysm, AAA, fever of unknown origin

19. EXPLANATION

C. Fissures within the intraluminal thrombus. Data is contradictory regarding the effect of intraluminal thrombus on risk of rupture (Bhatt 2007; Labruto 2011; Parr 2011). As the AAA increases in diameter, there is decreased laminar flow and subsequent increase in thrombus formation. Some data supports that thrombus protects the weakened aortic wall against pulsations of arterial flow, thereby decreasing risk of rupture. However, a published case series of autopsy studies suggests that 80% of patients who died from AAA had rupture sites at areas of thickest intraluminal thrombus (Labruto 2011). Further study has shown that the aortic wall associated with thrombus is thinner and weaker.

Three characteristics of intraluminal thrombus have been identified as increasing AAA rupture risk: fissures within the thrombus, increased calcifications, and rate of thrombus size and growth (Labruto 2011). When evaluating intraluminal thrombus by ultrasound, areas of decreased echogenicity within the thrombus are often consistent with fissures and dissections. Color Doppler placed

over the AAA can register fissures as areas of flow within the intraluminal thrombus (Bhatt 2007; Labruto 2011). These cracks and fissures are suggestive of increased risk of rupture, though there is low specificity. Calcifications of the aortic wall can indicate decreased wall compliance, a part of a multifactorial analysis, along with gender, diameter, and aneurysm morphology, among others, to help predict risk of rupture. Ultrasound is not as specific as CT for demonstrating calcifications within the thrombus (Labruto 2011).

Learning Points: Three characteristics of intraluminal thrombus rupture are thrombus fissure, increased calcifications and rate of thrombus growth.

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Labruto F, Blomqvist L, Swedenborg J. Imaging the intraluminal thrombus of abdominal aortic aneurysms: techniques, findings, and clinical implications. *J Vasc Interv Radiol*. 2011 Aug;22(8):1069–1075.

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Keywords/Tags: AAA, intraluminal thrombus, prediction of rupture

20. EXPLANATION

B. CT angiography of the aorta and vascular surgery consult. The 2018 Society for Vascular Surgery practice guidelines for the management of AAA recommend considering repair for asymptomatic fusiform AAA >5.4 cm and surveillance for smaller aneurysms (Chaikof 2018). Given the aneurysm size on the image, as well as degree of atherosclerosis and guidelines recommending repair for AAA >5.4 cm, choice B is the most appropriate answer. Multiple studies have demonstrated an overlap between atherosclerotic burden and presence of AAA. Increased burden is thought to decrease aortic wall compliance, thus increasing peak wall stress and risk of rupture (Hernesniemi 2015). B-mode ultrasound imaging detects atherosclerotic plaque as protrusions of the intima-media into the vessel lumen. Early plaque will be echo-lucent due to the large lipid core, whereas increased fibrosis and calcification causes advanced plaque to appear as echogenic, as seen in Figure 6.24. Inflammatory aneurysms are associated with chronic abdominal pain, weight loss, and elevated erythrocyte sedimentation rate and account for ~10% of AAA. Steroids have been shown to decrease inflammation and ease symptoms prior to vascular repair (Jim 2017). They are characterized by a marked inflammatory response in the adventitia of the aorta and by a thick rind (≥1 cm) on contrast enhanced CT. Ultrasound may distinguish inflammatory AAA by this thick rind of tissue, but there is high user variability in making this diagnosis with ultrasound (Bhatt 2007). Immediate resuscitation and uncrossmatched blood is an appropriate level of intervention for an unstable ruptured AAA; in this case the patient has normal vital signs and no symptoms.

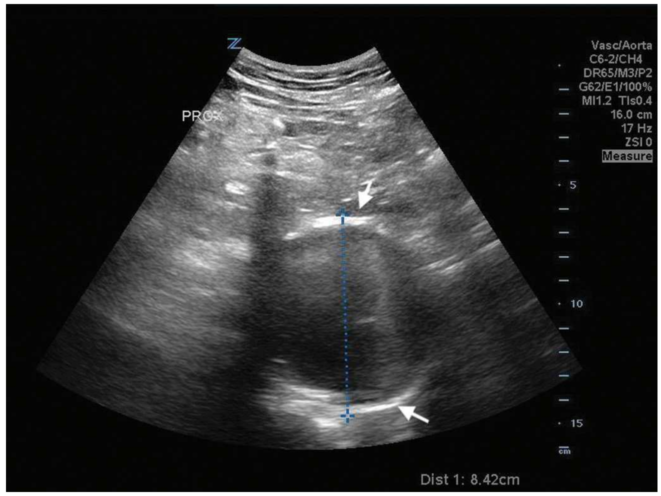

Figure 6.24 **Short axis view of abdominal aortic aneurysm.** Arrows point to plaque burden.

Learning Points: Asymptomatic incidental findings of a AAA >5.4 cm requires ED CT and vascular surgery consult.

Smaller asymptomatic aneurisms should prompt vascular surgery referral for surveillance.

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Keywords/Tags: AAA, atherosclerosis, inflammatory AAA, asymptomatic AAA, symptomatic AAA

21. EXPLANATION

C. Bedside ultrasound to evaluate the aorta. Hydronephrosis is a described complication of both unruptured AAA and expanding hematomas from retroperitoneal rupture causing ureteral compression and urinary obstruction. Findings range from unilateral hydronephrosis (usually left kidney) to renal pelvis rupture (Lowe 2017; Galosi 2014). A subset of AAA, inflammatory AAAs, account for up to 10% of AAAs and, though there is a lower risk of rupture, the associated retroperitoneal fibrosis causes obstructive uropathy in an estimated 25% of cases (Bjorndalen 2013).

Though a noncontrast CT scan of the abdomen for further evaluation of her hydronephrosis is certainly reasonable, the patient is stable hemodynamically and, in the setting of no previous history of kidney stones and with known AAA risk factors, AAA must be in the differential. A bedside ultrasound investigation of the aorta can reliably determine presence of AAA; multiple studies have shown high sensitivity and specificity of ED performed bedside ultrasound in both ruling in and ruling out AAA (Tayal 2003). If AAA is present, a contrast enhanced CT scan of the abdomen is the preferred imaging modality where as a non-contrast CT is typical of urolithiasis workup.

Symptomatic care and discharge home are reasonable in a patient with known nephrolithiasis but, in this case, there is risk of missing a AAA diagnosis. Consult to urology is appropriate in a confirmed obstructive stone with uncontrolled pain, an infected stone, or a stone that does not appear to be passing spontaneously.

Learning Points:
- Hydronephrosis is an ultrasound finding that can be a complication of both ruptured and unruptured AAA.
- Flank pain and hydronephrosis in a patient with AAA should not be considered secondary to nephrolithiasis.

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Keywords/Tags: AAA, hydronephrosis, inflammatory AAA

22. EXPLANATION

C. The transverse diameter was not measured perpendicular to the long axis of the aorta on the ultrasound images. The tortuous, or ectatic aorta, has a higher incidence in the elderly due to increased atherosclerotic burden. One must use caution in measuring the tortuous aorta; it is easy to have erroneous values due to difficulty in following the aorta and in finding the correct plane for transverse and longitudinal views. Off-axis measurements can result in a falsely large diameter, as is the case here (Figure 6.25). Measuring perpendicular to the long axis of the aorta gives the most accurate values for aneurysmal size (Lema 2017).

The cylinder tangent effect occurs when the ultrasound beam is not perpendicular to the long axis and an off-center anterior-posterior measurement is obtained. The cylinder tangent effect leads to underestimation of the diameter of the vessel. Proper patient positioning improves image quality but does not explain the discrepancy in the two measurements. Intraluminal thrombus in an AAA usually leads to a measurement error of size underestimation, not overestimation (Lema 2017; Bhatt 2007).

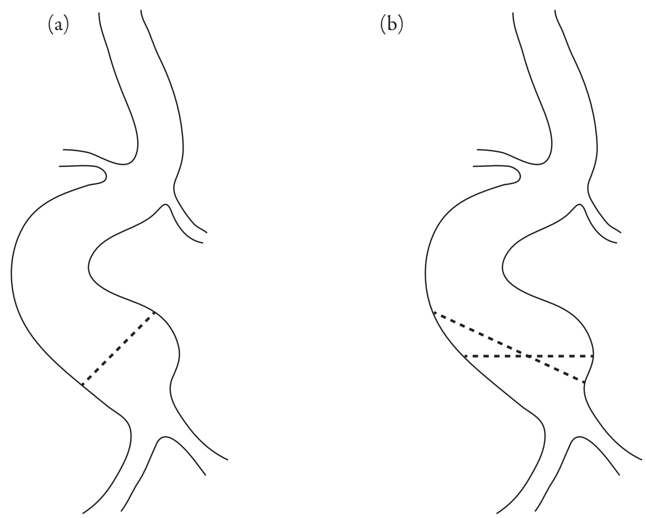

Figure 6.25 **Ectatic aorta measurements.** Placing the probe perpendicular and in-axis with the ectatic aorta yields accurate measurements of aorta diameter (a). Transverse (left–right) off-axis measurements lead to falsely elevated aneurysm size (b).

Learning Points: Transverse aortic measurements, when not taken perpendicular to an ectatic aorta, will result in falsely increased diameter measurements.

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Keywords/Tags: Tortuous aorta, ectatic aorta

23. EXPLANATION

D. Apply color Doppler to assess for flow. In longitudinal view of the aorta, one can easily either accidentally slide the probe to the right, or fan slightly to the right, thereby imaging the IVC. In short axis view, especially in metastatic or inflammatory conditions, periaortic lymph nodes (PAN) can be mistaken as the aorta, given their location anterior and lateral to the aorta.

Differentiating the IVC and PAN from the aorta is important in these situations. Identification of the aorta immediately anterior to the vertebrae helps differentiate the two. Placement of color Doppler can also help; PAN will have no color flow. The IVC is usually collapsible with light pressure. If the IVC does not collapse and debate remains, scan cephalad in a transverse plane; the IVC will pass through the diaphragm and the trunks of the SMA and celiac artery will become visible on the aorta (Reardon 2013).

In this particular image, we have a short axis view of the aorta with enlarged PAN visible (Figure 6.26a) and with color Doppler (Figure 6.26b, Video 6.18). Compression will not help differentiate the two, as PAN and the aorta are not compressible. Increasing depth, though frequently an appropriate next step when landmarks are not easily visible, is not suitable as landmarks are appropriate in this image. Increasing frequency is also an appropriate next step when the object of interest is in a shallow field, such as a superficial vessel or the gallbladder in a thin body habitus, and improved image quality and resolution is sought.

If enlarged PAN are identified on the AAA ultrasound, consider metastatic intra-abdominal disease on the differential.

Learning Points: Identify additional structures (in particular the IVC and para-aortic lymph nodes) that can be mistaken for the aorta.

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Keywords/Tags: AAA, IVC, paraaortic lymph nodes, depth, frequency, color Doppler

24. EXPLANATION

B. Consult vascular surgery for emergent surgery. Given a clinical scenario concerning for a ruptured AAA (abdominal pain, back pain, and/or flank pain with sudden onset syncope, shock, or hypotension), a finding of AAA on ultrasound with hemodynamic instability warrants immediate transfer to the operating room for surgical management without confirmatory advanced imaging. Stable patients may proceed to imaging by CT angiogram to better define anatomy and facilitate operative repair (see Figure 6.27) (Bhatt 2007; Burger 1999). CT angiogram, traditional angiogram, and formal ultrasound by radiology are not correct since they all delay definitive operative treatment and place this unstable patient at risk by leaving the ED. Bedside ultrasound is sufficiently sensitive and specific for this diagnosis given the appropriate clinical scenario (Tayal 2003; Costantino 2005; Rubano 2013). One study assessing the accuracy of bedside ED ultrasound in diagnosing AAA demonstrated 100% sensitivity (95% confidence interval [CI] = 89.5–100), 98% specificity (95% CI = 92.8–99.8), 93% positive predictive value (27/29), and 100% negative predictive value (96/96) (Tayal 2003).

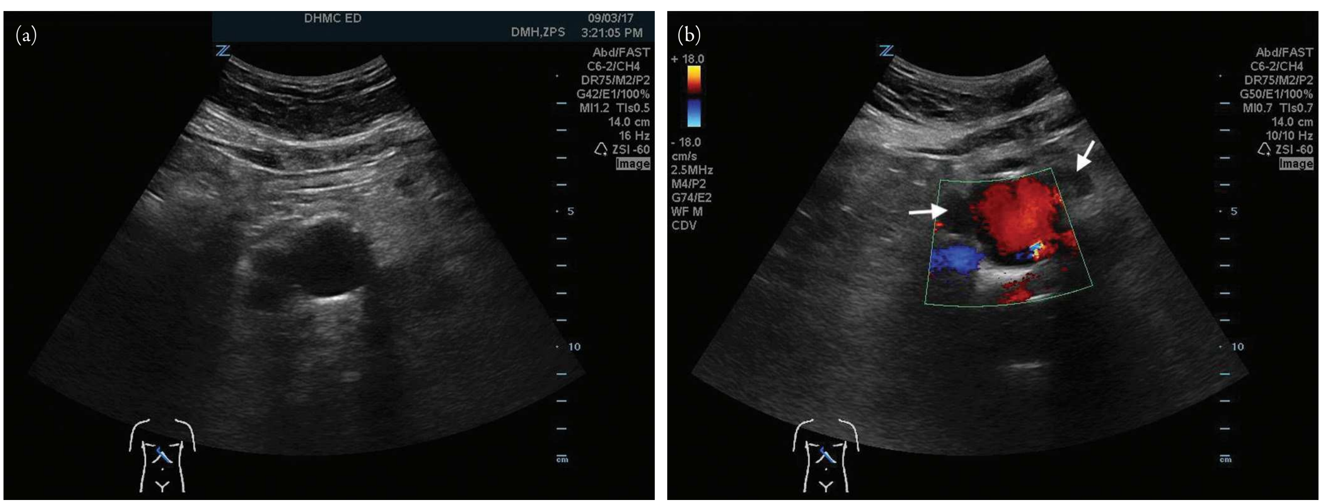

Figure 6.26 (a) **Short axis view of aorta with periaortic lymph nodes.** (b) **Short axis view of aorta with color Doppler and periaortic lymph nodes.** Arrows point to periaortic lymph nodes.

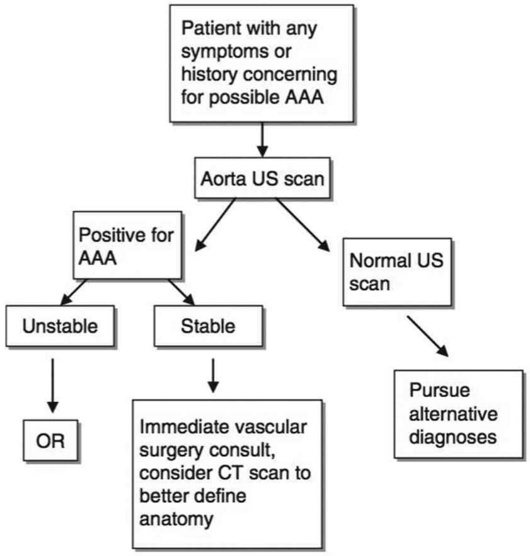

Figure 6.27 **Algorithm used to evaluate potential abdominal aortic aneurysm using bedside ultrasound.** Adapted from Figure 5.21 of Noble VE, Nelson BP. *Manual of Emergency and Critical Care Ultrasound*. 2nd ed. New York, NY: Cambridge University Press; 2011.

Learning Points: Ultrasound findings of an AAA in an unstable patient in the clinical context of a ruptured AAA warrants direct transfer to OR for surgical repair without intermediate advanced confirmatory imaging.

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Keywords/Tags: Ruptured abdominal aortic aneurysm, ruptured AAA, abdominal aortic aneurysm, clinical considerations

25. EXPLANATION

D. AAAs are unlikely to rupture intraperitoneal. The majority of ruptured AAA's leak into the left retroperitoneum and, therefore, a ruptured AAA may not cause free intraperitoneal fluid (Burger 1999; Golledge 1999; Catalano 2005). Given the high sensitivity of bedside ultrasound for AAA, rupture of the aneurysm should be assumed in a patient presenting with abdominal pain and hemodynamic instability or syncope who is found to have a AAA on bedside ultrasound. Additional ultrasound findings in ruptured AAA include AAA deformation, luminal thrombus inhomogeneity or disruption, floating intraluminal thrombus layer, and hypoechoic areas within or adjacent to the aorta wall (Catalano 2005). Bedside ultrasound has little utility in the evaluation of retroperitoneal bleeding due to difficulty visualizing the retroperitoneal space. However, retroperitoneal bleeding infrequently causes elevation of the left kidney (visualized ~5% of the time). In the event of an intraperitoneal rupture, the FAST exam is insensitive for low-volume free fluid. Previous studies have demonstrated that up to 400–600 ml of free intraperitoneal fluid may be missed on the initial FAST exam (Branney 1995).

Learning Points: A negative FAST exam does not rule out ruptured AAA as rupture rarely occurs intraperitoneal and retroperitoneal hemorrhage is identified in only 5% of ultrasounds.

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Keywords/Tags: FAST assessment for ruptured AAA, focused assessment with sonography for trauma, FAST, ultrasound assessment for retroperitoneal hematoma

26. EXPLANATION

D. Outpatient vascular surgery referral for nonemergent follow-up. Findings of AAA on bedside ultrasound in patients with abdominal, back, or flank pain, syncope, or hypotension should be followed by confirmatory CT angiogram in stable patients to assess for rupture and emergent vascular surgery consultation for repair in the unstable patient (Ernst 1993; Ouriel 1992; Isselbacher 2005; Brown 2003). While this patient does have a significant AAA and requires vascular surgery follow-up, there are no signs of rupture on CT. Further, he has another explanation for his symptoms suggesting that the AAA is an incidental finding. AAAs <4 cm have a 2% per year risk of rupture, AAAs 4–5 cm have

a 3%–12% per year risk of rupture, and AAAs >5 cm have a 25%–41% risk of rupture (Limet 1991). This patient needs nonemergent outpatient follow-up to monitor for enlargement of the aneurysm but does not need any acute intervention at this time. Due to his relatively low risk of rupture, he does not need urgent follow-up within the next 7 days.

Learning Points: Incidental discovery of a non-rupturing AAA requires out pt follow up.

As a AAA increases in diameter so does the risk of rupture with AAA >5 cm incurring a 25–41% yearly risk.

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Keywords/Tags: Incidental AAA, asymptomatic AAA, indications for surgical referral for asymptomatic AAA

27. EXPLANATION

C. Pulsed wave Doppler. While the aorta tends to appear more pulsatile than the IVC in color Doppler mode, the IVC may also appear pulsatile given its proximity to the aorta (Noble 2011). Therefore, the aorta should not be identified based solely on physical pulsation or pulsatility on color Doppler flow. Identify the IVC and aorta adjacent to each other in short axis view, superficial to the spine. Color Doppler may aid identification of vascular structures if significant artifact exists in the area of interest (Battaglia 2010). Nonetheless, pulsed-wave Doppler is superior to color Doppler in that it can differentiate the triphasic intermittent waveform of the aorta (Figure 6.28a) from the more continuous monophasic venous waveform of the IVC (Figure 6.28b) (Fadal 2014). Power Doppler would be subject to the same pitfalls as color Doppler and additionally does not give information on direction, and M-mode does not assess flow. Additionally, the IVC can sometimes be compressed using the probe, whereas the aorta is not compressible; however, this technique may be unreliable in obese patients.

Learning Points: Pulsed wave Doppler (rather than color Doppler) is preferable to identify the arterial waveform of the aorta as compared to the venous waveform of the IVC.

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Noble VE, Nelson BP. *Manual of Emergency and Critical Care Ultrasound*. 2nd ed. Cambridge, UK: Cambridge University Press; 2011:115–132.

Keywords/Tags: Anatomical considerations, pulsed-wave Doppler, differentiating IVC versus aorta

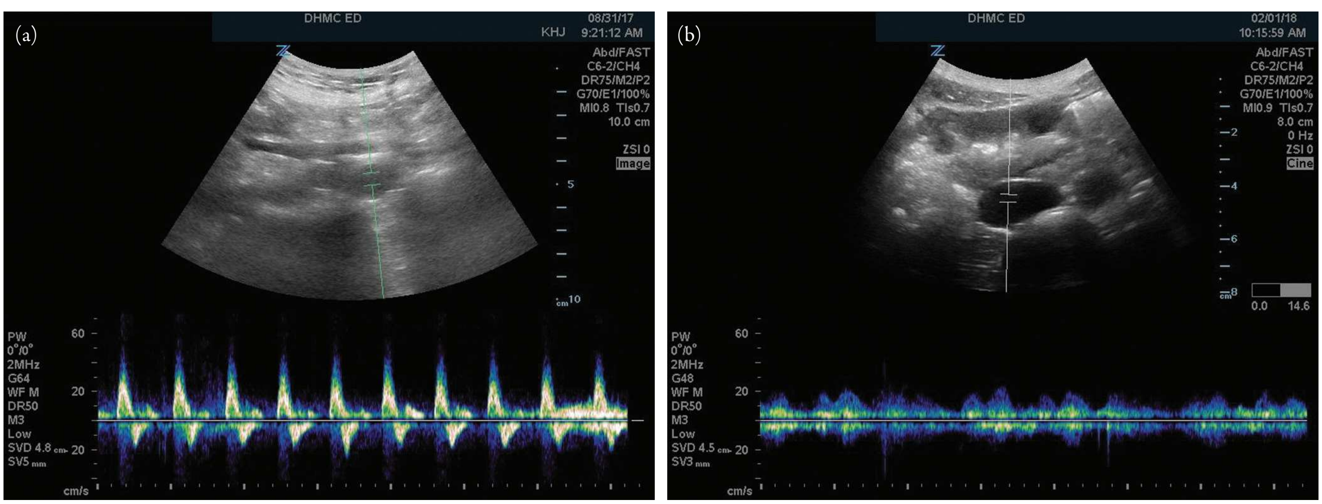

Figure 6.28 (a) **Pulsed-wave Doppler triphasic arterial waveform.** (b) **Monophasic venous waveform.**

28. EXPLANATION

C. Increase the depth. While the image depicts a vascular structure in the abdomen that appears to be the aorta, the depth is too shallow to visualize all of the vessel. This is a common error, especially in obese patients. The abdominal aorta is found deep in the retroperitoneum (Wu 2010). It cannot be definitively identified until image depth is increased enough to visualize the hyperechoic outline of the anterior spine and the underlying horseshoe-shaped shadow known as the "horseshoe sign." With sufficient imaging depth assured, the abdominal aorta is identified overlying the spine slightly to the patient's left side, adjacent to the IVC (Noble 2011; Cosby 2013). The image has acceptable gain; however, the depth is too shallow to visualize the posterior wall for measurements.

Learning Points: Optimization of depth is of paramount importance when attempting to visualize the aorta. Start deep to identify the spine and decrease depth to optimize visualization and avoid diagnosing a more superficial vessel as the aorta.

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Keywords/Tags: Technique and normal findings, visualizing the abdominal aorta

29. EXPLANATION

B. 1.5 cm. While not considered part of the aorta ultrasound study, POCUS evaluation of iliac aneurysms in patients with symptoms localized to the lower quadrants or inguinal region can be a useful diagnostic tool. Iliac arteries greater than 1.5 cm in women and greater than 1.8 cm in males are considered aneurysmal (Richardson 1998). Isolated iliac artery aneurysms (IAAs) are rare with a ~2% incidence, although when combined with coexisting AAA increase in incidence to 10%.

IAAs are associated with significant morbidity and mortality. Five-year rupture rates range from 14% to 70%. The data suggests that 33%–40% of patients with IAAs present initially with rupture, which can be rapidly fatal if not recognized and treated (Richardson 1998; Dix 2005; Santilli 2000). Mortality rates for ruptured IAAs are as high as 58% (Parry 2001). The average size of a ruptured isolated iliac aneurysm is 7.7 cm (range 2–13 cm) (Dix 2005).

IAAs may rupture into the retroperitoneum or intraperitoneum, much like AAAs. They may also rupture into the rectum, ureter, bladder, iliac veins, and rectus sheath. Rupture often results in hemodynamic instability but can have a varied clinical presentation, involving abdominal pain (31.7%), urological symptoms (28.3%), neurological symptoms (18.3%), groin pain (11.7%), hip or buttock pain (8.3%), and gastrointestinal symptoms (8.3%) (Dix 2005).

Given this high mortality, prompt diagnosis and treatment are paramount and can be facilitated by bedside ultrasound, which correlates closely with CT angiogram in terms of diagnostic sensitivity and accuracy of aneurysm measurement (Rama 2003). IAAs are treated surgically with endovascular coiling, stenting, or open repair.

Learning Points: Iliac aneurisms are defined by gender, >1.5 cm for females and >1.8 cm for males. Aneurisms under 3 cm are generally surveilled with ultrasound and the average diameter of those that are isolated and rupture is 7.7 cm.

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Keywords/Tags: Iliac artery aneurysm

30. EXPLANATION

C. Consult vascular surgery, begin anticoagulation if no contraindications, and order CTA of the abdomen with run-offs into the lower extremities to evaluate for complete aortic occlusion. This patient has complete occlusion of the abdominal aorta. This rare condition, which may be thrombotic or embolic, predominantly affects female smokers with dyslipidemia and is associated with low-flow states secondary to congestive heart failure or dehydration (Hirsch 2008; Efstratiadis 2004). In patients without collateral flow, it may be limb threatening. Mortality ranges from 31% to 52% and is compounded by associated occlusion of renal and spinal arteries (Hirsch 2008; Babu 1995). While CTA or magnetic resonance angiography (MRA) should be ordered to confirm

the diagnosis and aid in surgical management given their high sensitivity and specificity, bedside ultrasound of the abdominal aorta, iliac arteries, and popliteal arteries can be useful to expedite diagnosis, medical management, and activation of a surgical team. In severe cases, ultrasound is an effective screening tool, with a sensitivity and specificity of 91% and 93%, respectively (Langsfeld 1988). If this patient instead had aortic dissection, an intraluminal flap and variable flow direction on color Doppler may have been seen rather than thrombus occluding the entire lumen. The thrombus in this image obstructs flow, unlike a AAA associated thrombus in which intraluminal flow would still be present; therefore, this patient's symptoms are not likely caused by a AAA. Additionally, given the sensitivity of bedside ultrasound at detecting intraluminal thrombus, formal Doppler is not the appropriate next step.

Learning Points: Acute aortic occlusion has high morbidity and mortality. Bedside ultrasound is a reasonable screening tool for acute aortic occlusion while awaiting CTA. Identification of such pathology early in a patient's course can expedite definitive imaging and surgical consultation.

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Keywords/Tags: Aortic occlusion

31. EXPLANATION

D. Order CT angiogram of the chest, abdomen, and pelvis. Bedside ultrasound has a role in identifying direct and indirect signs of acute aortic dissection. Direct signs include an intraluminal flap with bidirectional color Doppler flow and an intramural thrombus visualized on cardiac, suprasternal notch, or abdominal views. Indirect signs include dilated aortic root >4 cm, acute pericardial tamponade, and acute aortic regurgitation on cardiac views. Bedside emergency physician TTE has demonstrated a sensitivity of only 54% for detecting direct signs and 88% for detecting combined direct and indirect signs based on one recent study (Nazerian 2014). In this study, 5.6% of low pretest probability patients with aortic dissection had no sonographic signs of dissection on TTE. A separate study of cardiologists demonstrated significantly higher sensitivity of direct sonographic signs for type A aortic dissection on TTE (87%), suggesting that skill level and experience may affect sensitivity (Cecconi 2012).

Although TTE can increase suspicion for acute aortic dissection, it is not sensitive enough to rule it out—even with low pretest probability. Findings suggestive of acute aortic dissection on TTE warrant confirmatory imaging with CT or MRA in the stable patient or bedside TEE in the unstable patient. All have excellent sensitivity and specificity for type A dissection (Bhatt 2007; Coady 1999). While TTE is not sufficiently sensitive to rule out dissection, it may prompt advanced imaging, thus expediting definitive diagnosis and mobilization of a surgical team and proving life-saving given the high-risk, time-sensitive nature of this disease (Pare 2016). Since this patient is hemodynamically stable, he may proceed to CT for imaging.

Learning Points: Bedside ultrasound is not sensitive enough to rule out abdominal or thoracic aortic dissection.

In the hemodynamically unstable patient primary and or secondary signs significantly increase the likelihood of the disease and may expedite surgical management.

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Pare JR, Liu R, Moore CL, et al. Emergency physician focused cardiac ultrasound improves diagnosis of ascending aortic dissection. *Am J Emerg Med*. 2016;34(3):486–492.

Keywords/Tags: Aortic dissection

32. EXPLANATION

B. The patient should receive screening bedside ultrasound prior to advanced imaging while waiting for advanced imaging if it is not immediately available. Although no mortality benefit was shown, a recent study demonstrated that bedside TTE, when used to identify dilation of the aortic root (>4 cm) in patients with suspicion for acute type A aortic dissection, significantly decreased time to definitive diagnosis and decreased misdiagnosis rates (Pare 2016). The definitive diagnosis of acute aortic dissection is made by CTA or MRA in stable patients and by TEE in unstable patients (Bhatt 2007; Coady 1999). Bedside TTE is not sensitive or specific enough in isolation to rule out dissection and should always be followed by advanced imaging if

clinical suspicion for dissection exists. Various studies report sensitivities of 59% to 83% and specificities of 63% to 93% of TTE for the diagnosis of aortic dissection (Nazerian 2014; Huish 2011). Advanced imaging should not be delayed by bedside TTE; however, if advanced imaging is not immediately available, bedside TTE can direct resuscitation and expedite advanced imaging. Rapid diagnosis of type A dissection is crucial, as the mortality rate increases 1% to 2% per hour without surgical treatment and mortality risk is concentrated within a few hours of presentation (Coady 1999). Once dissection into the pericardial sac occurs (Figure 6.29, Video 6.19), the patient may rapidly decompensate. This patient required pericardiocentesis after cardiopulmonary arrest in the ED eventually regaining pulses, transport to the operating room, with successful operative intervention.

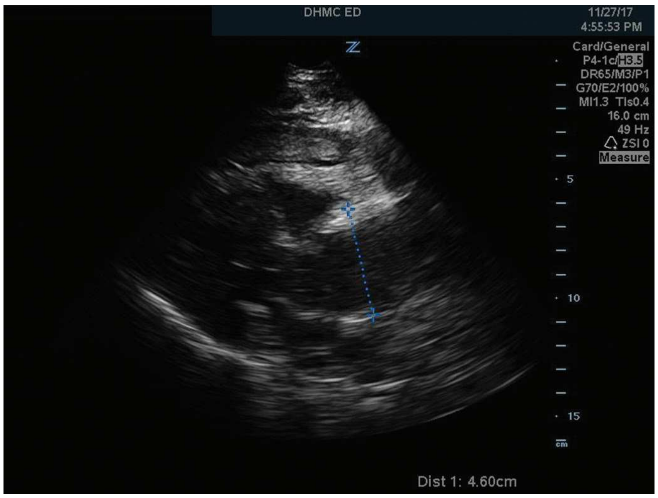

Figure 6.29 **Dilated aortic root and hemopericardium secondary to aortic dissection.**

Learning Points: Although bedside ultrasound is not sensitive enough to rule out acute aortic dissection, it should be performed on any patient in whom there is suspicion for dissection since it has been found to significantly reduce time to definitive diagnosis.

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Keywords/Tags: Aortic dissection

33. EXPLANATION

B. Bedside TEE. While CTA and MRA are sensitive and specific in the diagnosis of acute type A aortic dissection, they are not practical in unstable patients who require intensive monitoring in the ED. While a bedside TTE may lead a clinician toward the diagnosis of dissection and expedite definitive diagnosis and management, it is neither sensitive nor specific for this diagnosis (Nazerian 2014). TTE is also unable to adequately visualize the mid- and distal ascending aorta, transverse arch, and descending aorta (Moore 2002). TEE can be conducted at the bedside and is highly sensitive and reasonably specific for type A dissection, making it the preferred diagnostic modality (Figure 6.30, Video 6.20). Studies have traditionally demonstrated sensitivity and specificity of TEE of 96% to 100% and 77% to 94%, respectively, for type A dissection (Nienaber 1993). A more recent study demonstrated sensitivity and specificity of 98% and 95%, respectively (Shiga 2006). Although traditionally conducted by cardiologists, TEE is now increasingly used by emergency physicians and anesthesiologists (Arntfield 2016). Additionally, a recent study assessing the accuracy of bedside TTE in the diagnosis of type A aortic dissection by emergency physicians demonstrated a sensitivity, specificity, positive and negative predictive value of 100% in a subgroup of hypotensive patients. This suggests a role for TTE in the diagnosis of aortic dissection in the ED; however, further research is needed (Nazerian 2014).

Learning Points: The imaging modality of choice for investigation of aortic dissection in the hemodynamically unstable patient is TEE.

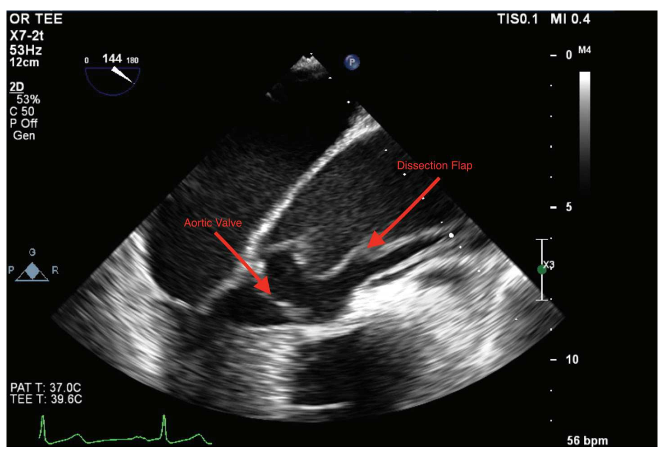

Figure 6.30 **Transesophageal mid-esophageal long axis view showing aortic dissection.** This transesophageal view if the aortic root clearly demonstrates a dissection flap abutting the aortic valve. *Courtesy of Dr. Peter Burrage MD, Dartmouth-Hitchcock Medical Center, Lebanon, New Hampshire.*

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Keywords/Tags: Aortic dissection, transesophageal echocardiogram, TEE

34. EXPLANATION

C. 4 cm. The marked structure is the proximal aortic root on a parasternal-long view of a TTE. Measurements of <4 cm are considered normal, 4.0 to 4.5 cm dilated, and >4.5 cm aneurysmal (Kennedy 2015). There is considerable normal variation in aorta diameter between healthy individuals. Diameter does increase with body surface area; however, 4 cm is considered the upper limit of normal (Hiratzka 2010). Sonographic measurements of the aortic root correlate well with measurements on CT scan (Taylor 2012). Unfortunately, given that the aorta diameter exhibits both normal variation and variation due to several other pathologic states, sonographic measurement lacks adequate sensitivity and specificity to definitively diagnose type A aortic dissection (Nazerian 2014). Nonetheless, a recent study demonstrated that in patients with suspected acute type A aortic dissection, bedside TTE identification of a dilated aortic root >4 cm was associated with decreased times to definitive diagnosis and decreased misdiagnosis rates (Pare 2016).

The proximal aorta is best measured at the widest section (which is usually the sinus of Valsalva), from outer wall anteriorly to inner wall posteriorly, during diastole, in the parasternal-long axis view (Hiratzka 2010). Care must be taken to orient the probe perpendicular to the long axis of the aorta to avoid overestimating diameter. The probe should be swept side to side to capture the maximal width of the vessel to avoid diameter underestimation due to cylinder tangent effect in a longitudinal view (Kennedy 2015).

The aortic root measurements should be taken in the parasternal long axis perpendicular to the aortic wall at the area of greatest diameter, usually the sinus of Valsalva lying within the red circle (green line in Figure 6.12).

Learning Points: Aortic root diameter varies by body surface area, however, maximal diameter should be <4 cm measured in parasternal long axis from outside of the anterior wall to inside of the posterior wall. An aortic diameter >4 cm should increase suspicion of aortic dissection in the correct clinical scenario.

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Keywords/Tags: Thoracic aorta, acute aortic dissection, aortic root dissection

35. EXPLANATION

C. Specific but not sensitive. This patient has an acute type A aortic dissection demonstrated by an intimal flap (indicated by arrow in Figure 6.13). ED bedside TTE can aid in diagnosing this condition via direct and indirect signs. Direct signs include an intraluminal flap with bidirectional color Doppler flow or an intramural thrombus visualized on cardiac, suprasternal notch, or abdominal views. Indirect signs include a dilated aortic root >4 cm, pericardial tamponade, or acute aortic regurgitation on cardiac views. A recent study of emergency physician TTE has demonstrated sensitivities of only 54% for direct signs and 88% for combined direct and indirect signs, confirming that this remains an inadequate rule-out modality (Nazerian 2014).

Despite limited sensitivity, bedside TTE has significant specificity for type A dissection (94%) when a direct sign is visualized, and this has been replicated in several studies (Cecconi 2012). Interestingly, when patients had several risk factors for dissection, sensitivity of TTE increased

to 98%, and further increased to 100% in hypotensive patients. Nonetheless, 14 patients falsely identified as having a direct sign might have undergone unnecessary surgical repair without confirmatory imaging, so confirmatory imaging is compulsory.

Reverberation and side-lobe artifact can mimic the presence of an intimal flap, decreasing specificity, so the aorta should be evaluated from multiple probe angles to ensure a suspected intimal flap is independent of surrounding structures and visualized only within the lumen. Additionally, color flow Doppler can be useful in demonstrating differential flow on either side of the flap, further confirming that the flap is not artifact (Hiratzka 2010; Fojtik 2007; Bhatt 2007).

Learning Points: Bedside TTE sensitivity is insufficient to rule out thoracic aortic dissection but has good specificity. If thoracic aortic dissection is seen on TTE it can expedite definitive operative management.

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Keywords/Tags: Thoracic aorta, aortic dissection, intimal flap

36. EXPLANATION

C. HI-MAP. In 2009 Weingart et al. published a systematic ultrasound approach to the hypotensive patient titled "The RUSH Exam: Rapid Ultrasound for Shock and Hypotension." This systematic performance of cardiac, pulmonary, abdominal (free fluid, aorta), and deep venous thrombosis (DVT) ultrasound was an expansion of already described sequenced ultrasound studies such as the UHP, FAST, ACES, and Trinity protocols (Rose 2001; Jones 2004; Bahner 2002). In its original description HI-MAP (Heart, IVC—Morrison's pouch and FAST views with hemothorax windows, aorta, pneumothorax) described the sequencing and indications for performing each portion of the exam. Another expanded description of the RUSH was published by Perera et al. in 2010.

The ultrasound image displayed in this question is of an AAA. In the setting of critical illness without a known reason for hypotension, the provider should begin with cardiac ultrasound and advance through the HI-MAP acronym. If there is high clinical suspicion for a specific pathology, such as a AAA, it is reasonable to start with most likely organ system.

TAPSE stands for "tricuspid annular plane systolic excursion" and is a measurement taken on cardiac ultrasound when evaluating right ventricular systolic function. EFAST stands for "extended focused assessment with sonography in trauma" and is a systematic approach consisting of a limited cardiac exam without evaluation for DVT or AAA. FOCUS stands for "focused cardiac ultrasound" described by multiple societies and does not evaluate organ systems other than the heart (Labovitz 2010).

Learning Points: Aortic ultrasound is often included in multisystem ultrasound protocols typically utilized in critically ill hypotensive pts.

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Keywords/Tags: AAA, RUSH exam

37. EXPLANATION

A. Decrease frequency. The image (Figure 6.14, Video 6.10) demonstrates the aorta deep within the abdomen. Image optimization is performed by manually decreasing the frequency, allowing ultrasound waves to penetrate more deeply into such tissues as the obese abdomen. Each probe has a specific frequency range it operates within which can be manually adjusted. Decreasing frequency results in decreased image resolution. This is easy to do and, along with depth and gain, is part of the initial approach to image optimization. Figure 6.31 and Video 6.21 demonstrate decreased frequency without harmonics demonstrating clearer aortic walls.

Figure 6.31 **Optimized frequency.**

Depth is optimized as the aorta sits low within the focal zone. Increasing depth any more would add too much space deep to the organ of interest, making interpretation difficult. The focal zone(s) could be adjusted to improve resolution in the far field, but it is not listed as an answer choice. Pulse repetition period (PRP) and pulse repetition frequency (PRF) are properties related to the depth. As you move deeper into the body the number of pulses generated in 1 second (or PRF) decreases, as the probe needs to spend more time listening for pulses returning from deep structures. Inversely, the PRP or period between pulse generation increases. The ultrasound wavelength cannot directly be adjusted by the sonographer as it is a property of the ultrasound source and the medium.

Learning Points: When encountering poor image quality, having a strong command of machine operation and functions such as frequency, gain, depth, time gain compensation, and focal zones can provide more interpretable images.

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Keywords/Tags: Machine setup, transducer choice, ultrasound physics, image optimization

38. EXPLANATION

A. Aortoenteric fistula. The clinical presentation of hematochezia with history of surgical manipulation of the aorta should prompt aortoenteric fistula consideration. Though CT angiography is the imaging modality of choice (Hallet 1997), patient stability, extended wait times, or radiology protocols may lead to diagnostic delay. In these circumstances POCUS may demonstrate overt fistula or AAA, which could expedite surgical consultation and aggressive resuscitation.

Case reports have demonstrated aortoenteric fistula identification with POCUS (Mackenzie 2015). Figure 6.15 demonstrates an AAA with aortic stent in place and an anechoic protrusion from the aorta. Color flow should be utilized in an attempt to demonstrate aortic blood flow and communication with overlying bowel, which may be fluid filled. Findings can be confirmed on CT.

Aortoenteric fistulas are divided into two categories, primary (PAEF) and secondary (SAEF) aortoenteric fistula. PAEF is extremely rare with a prevalence of less than 1% and results when a native aortic aneurysm or aorta diseased from infection, inflammation, or tumor forms a fistula with surrounding bowel. SAEF is more common, accounting for up to 1.6% of aortic repair complications (Calligaro 1992). It results when a previously reconstructed or stented aorta fistulizes with proximate, bowel. AAA is the most common risk factor and 75% of fistulization occurs with the duodenum. Rarely the aorta or iliac arteries can fistulize with vascular structures such as the left renal vein and IVC or other areas of the small bowel in similar fashion (Hallett 1997; O'Mara 1977).

Learning Points: Recognize the potential for large AAA to form aortovenous/aortoenteric fistulas and the unique ultrasonographic findings associated with it.

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Keywords/Tags: Aorta fistula, fistula

39. EXPLANATION

C. CTA. The patient is likely suffering from an endoleak from his AAA endovascular stent. Endoleak is defined as blood flow through or around the wall of the stent into the aneurysm and can occur via several mechanisms. This is typically a more insidious process, and patients may be asymptomatic. If present, endoleak can increase the size of the aneurysm, putting the patient at risk for rupture. Post-repair surveillance is paramount as endoleak rates of 24% to 39% have been reported following surgery (Sato 1998)

Currently CTA is the imaging modality of choice to assess for endoleak (Sato 1998; Wolf 2000). In this case, the patient's symptoms and complex history generate a differential diagnosis, which is quite broad. It is conceivable that renal, aortic, pancreatic, musculoskeletal, or intestinal pathology may account for the patient's back pain. Should the patient's stent appear unchanged, CT is excellent at assessing for acute pathology in these other organ systems.

There is an increasing body of literature supporting the use of contrast-enhanced ultrasound in the evaluation and surveillance of endoleak; however, contrast is not widely utilized in the United States (Cantisani 2011; Bosch 2010). 2D color Doppler ultrasound is insensitive but highly specific and can be applied at the bedside quickly if suspicion is high or the patient is unstable. A major drawback to color Doppler is its inaccuracy in describing the endoleak type. Given its modest sensitivity, it should not be used to rule out endoleak (Raman 2003). MRA is an acceptable alternative with test characteristics approaching that of CT without the cumulative radiation burden; however, if the stent contains metal it may produce significant artifact, resulting in a nondiagnostic study (Bosch 2010).

Learning Points: Endovascular stent leak is a common complication of AAA repair. Ultrasound is specific but not sensitive thus CTA is the definitive imaging modality.

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Keywords/Tags: Contained rupture, graft leak, endoleak

40. EXPLANATION

B. Retroperitoneal hemorrhage. The image demonstrates a retroperitoneal hemorrhage (*) above the psoas muscle. POCUS is extremely sensitive and specific with good interrater reliability when identifying AAA (Kuhn 2000; Knaut 2005; Costantino 2005). Traditionally POCUS has been thought to be insensitive when identifying aortic rupture with contained or retroperitoneal hemorrhage (Chenaitia 2011).

However, Catalano et al. retrospectively found emergent ultrasound performed by radiologists to be 75.6% sensitive in detecting retroperitoneal hemorrhage in the setting of ruptured AAA. When considering contained retroperitoneal hemorrhage, it is important to have a strong knowledge of proximal anatomy as the pancreas, paraaortic lymph nodes, and psoas muscle have hypoechoic textures adjacent to the aorta and may be misidentified as hematoma. Placing Doppler on these areas may help differentiate active hemorrhage with hematoma from soft tissue. Ruptures most commonly occur at the largest diameter in the left posterior wall, causing left retroperitoneal hemorrhage, but may also rupture intraperitoneal, less commonly resulting in hemoperitoneum. Although POCUS is limited in its assessment of retroperitoneal hematoma, lateral or anterior displacement of the left kidney, aortic deformation, mobile thrombus within the lumen, and cracks in the intramural thrombus translating to the aortic wall may be visualized. If discontinuity of the aortic wall is identified, application of Doppler ultrasound may help identify active extravasation. Findings suggesting retroperitoneal extravasation should increase suspicion of rupture but alone cannot rule it out.

Choice A is incorrect since the patient did not have any previous AAA repair so endoleak is unlikely. Choice B is incorrect since color Doppler is used to identify aortoenteric fistula, which was not used in this case. Choice D is incorrect since the asterisk identifies a structure outside of the aorta, so intraluminal thrombosis is incorrect.

Learning Points: Visually identify contained aortic rupture and adjacent anatomy that may appear similarly.

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Keywords/Tags: Aorta tortuosity, contained rupture, hydronephrosis, dissection, fistula, iliac aneurysm, retroperitoneal hematoma

7.

HEPATOBILIARY ULTRASOUND

Viveta Lobo, Kenton Anderson, Cori Poffenberger, and Laleh Gharahbaghian

QUESTIONS

1. A 60-year-old female presents with epigastric abdominal pain and you are concerned she may have cholelithiasis. You are having trouble locating the gallbladder with your ultrasound. Which structures are helpful landmarks when identifying the gallbladder?

A. The portal triad and the median lobar fissure (MLF)
B. The duodenum and the aorta
C. The diaphragm and the stomach
D. The aorta and the inferior vena cava (IVC)

2. A 32-year-old male with known history of cholelithiasis and biliary presents with right upper quadrant (RUQ) pain, fever, and vomiting for 1 day. Clinically you suspect he now has acute cholecystitis. To confirm your diagnosis, you perform the ultrasound of his gallbladder shown in Figure 7.1 and Video 7.1. You visualize his gallbladder fundus, and he winces when you apply pressure.

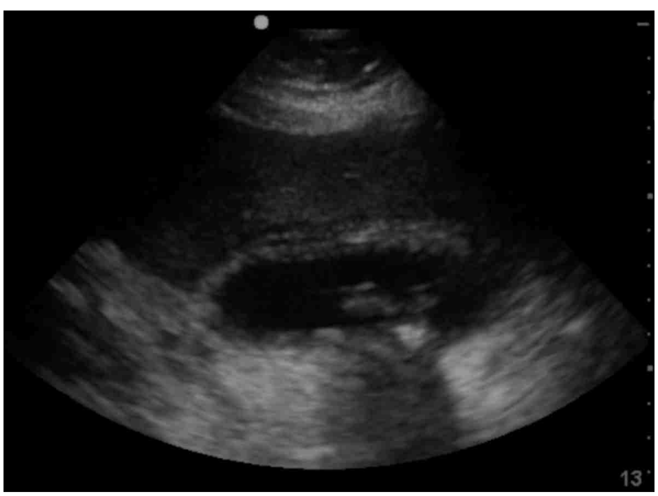

Figure 7.1

What are your findings?

A. Anterior gallbladder wall thickness >3 cm
B. Pericholecystic fluid
C. Positive Sonographic Murphy Sign
D. All of the above

3. You identify the portal triad and MLF in your 60-year-old patient. Now you want to locate and measure the common bile duct (CBD) so you obtain the ultrasound image shown in Figure 7.2. Which of the following correctly identifies the structures of the portal triad as labeled in Figure 7.2?

Figure 7.2

A. Portal vein (1), hepatic artery (2), CBD (3)
B. Hepatic artery (1), CBD (2), portal vein (3)
C. CBD (1), portal vein (2), hepatic artery (3)
D. Portal vein (1), CBD (2), hepatic artery (3)

4. A 90-year-old male with a history of cholecystectomy presents with upper abdominal pain for the past 2 days, associated with nausea and vomiting. You perform a RUQ ultrasound, obtaining the image shown in Figure 7.3 and Video 7.2, and measure his CBD at 9 mm. Which of these statements about this image is true?

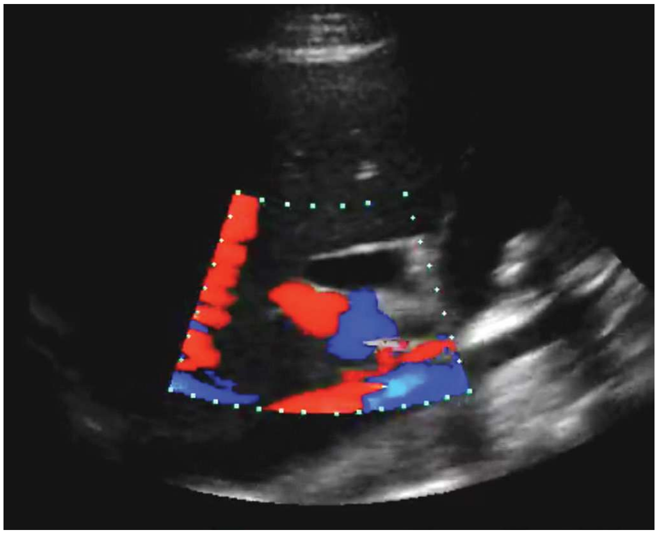

Figure 7.3

A. His CBD can be normal in size for his age, as well as for his post-cholecystectomy state.
B. His CBD is enlarged for someone of his age.
C. The size of the CBD does not change after cholecystectomy.
D. His portal vein is enlarged.

5. A 50-year-old male with a history of gallstones presents to the emergency department (ED), complaining of vomiting and jaundice. You are worried he may have cholangitis. You perform a RUQ ultrasound and measure his CBD as seen in Figure 7.4. Which of the following is correct?

Figure 7.4

A. His CBD is measured incorrectly: it should be measured outside-outside wall.
B. His CBD is measured correctly and is of normal size for his age.
C. His CBD is measured incorrectly: it should be measured inside-outside wall.
D. His CBD is measured correctly and is abnormal for someone of his age.

6. A 43-year-old female presents with RUQ pain with nausea for 3 hours duration after eating a cheeseburger and fries. You wish to assess for hepatobiliary pathology. Which probe can be used, in what anatomic region and in what technical manner?

A. High-frequency probe, intercostal region, lateral to medial
B. High-frequency probe, subcostal region, medial to lateral
C. Low-frequency probe, intercostal region, superior to inferior
D. Low-frequency probe, subcostal region, medial to lateral

7 A 40-year-old obese female presents with fever, non-radiating epigastric and RUQ pain, and non-bloody vomiting after eating a deli sandwich. She now complains of headache, light-headedness, and spasms in her hands. You notice on exam that she is jaundiced. Her hepatobiliary ultrasound scan is shown in Figure 7.5.

Figure 7.5

Which symptom is most specific for hepatobiliary pathology?

A. Fever
B. Vomiting
C. Epigastric and RUQ pain
D. Headache

8. A 50-year-old male presents with recurrent epigastric pain, nausea, and vomiting, which has now lasted 6 hours. His hepatobiliary scan is shown while he is in a supine position with the goal of assessing his

gallbladder neck. He states he is in too much pain from the pressure of the probe. What techniques can be used to help the patient tolerate the scan and optimize image resolution?

A. Place the patient on his left lateral decubitus position.
B. Ask the patient to take a deep breath.
C. Place the probe in the "X minus 7" or "X minus 12" location.
D. All of the above.

9. A 34-year-old female presents with epigastric pain and fever with a concern for acute cholecystitis. To properly perform a RUQ gallbladder ultrasound, what is the appropriate technique for a complete assessment in order to correctly identify and evaluate the gallbladder?

A. Increasing the depth to see the gallbladder in the near field
B. Only using B-mode to identify the gallbladder
C. Visualizing the gallbladder in longitudinal plane only
D. Wide fanning through the gallbladder in 2 orthogonal planes

10. A 36-year-old female with a history of gastritis presents with discomfort in her epigastric region and nausea for the last 6 hours. She is afebrile and is tender in her RUQ. Her biliary ultrasound is shown in Figure 7.6 and Video 7.3.

Figure 7.6

Which technique would best help assess her risk of developing cholecystitis?

A. Keep the patient supine.
B. Ask the patient to take a deep breath.
C. Evaluate the gallbladder in transverse plane.
D. Scan with the patient in lateral decubitus positioning.

11. A 56-year-old male presents with RUQ pain radiating to the flank with nausea and subjective chills. He is mildly tender in the RUQ and has no costovertebral angle tenderness to percussion. A gallbladder scan was performed and is shown in Figure 7.7 and Video 7.4.

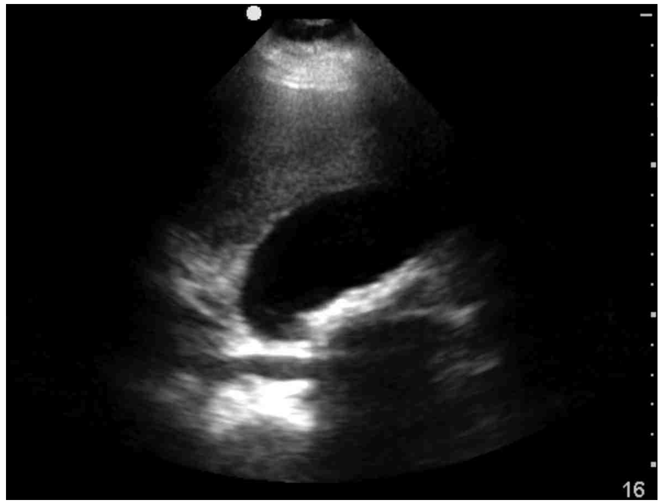

Figure 7.7

What ultrasound assessment will best determine whether this person has cholecystitis?

A. Apply pressure with the probe over the visualized gallbladder
B. Pulse wave Doppler of the gallbladder wall
C. Turn the patient to his left lateral decubitus position
D. Utilize M-mode to assess the echogenic material in the gallbladder

12. A 62-year-old female with a history of cholelithiasis presents with one day of RUQ pain and vomiting. She denies any fevers or chills. She has had recurrent

Figure 7.8

episodes for the past several years and has an appointment in the surgery clinic next month. Her exam shows RUQ tenderness without guarding or rebound. You perform the ultrasound shown in Figure 7.8 and Video 7.5.

What additional method(s) can help to confirm your suspicion of acute cholecystitis?

A. Look for pericholecystic fluid.
B. Elicit a positive Sonographic Murphy Sign.
C. Place color power Doppler on the gallbladder wall.
D. All of the above.

13. A 34-year-old female presents with RUQ pain, fever, and vomiting after eating pizza, stating she has had similar pain in the past. She is tachycardic and has tenderness in her epigastric area. You attempt a gallbladder scan with your patient in the supine position but encounter lots of bowel gas. You ask the patient to perform an inspiratory pause as well as flexing her knees, but still encounter bowel gas. To better assess the gallbladder, what is the next technique that you can employ?

A. Place patient supine, indicator caudad, and scan in the subcostal region.
B. Place patient in right lateral decubitus, indicator cephalad, and scan in the subcostal region.
C. Place patient in left lateral decubitus, indicator toward patient's right, and scan in the left posterior-axillary line.
D. Place patient in left lateral decubitus, indicator toward patient's right, and scan in the subcostal region.

14. A 73-year-old thin female with a history of diabetes presents for vague abdominal pain. She is alert and in no acute distress, and her vital signs are within normal limits. She is mildly tender to her RUQ and right flank, so you decide to perform a RUQ ultrasound, shown in Figure 7.9 and Video 7.6.

Figure 7.9

What is the cause of this finding?

A. A congenital fold in the gallbladder fundus
B. Complicated sludge
C. Cholangiocarcinoma
D. A septation in the gallbladder

15. One a scanning shift, you employ an X minus 7 technique, with the indicator pointed cephalad, to find the gallbladder in longitudinal axis of your first patient. On your second patient, employing the same technique, the gallbladder appears in an oblique transverse axis. What are the factors that account for variability in gallbladder position?

A. The relative position of the gallbladder to the liver
B. The relative position of the duodenum to the gallbladder
C. The patient's positioning
D. All of the above

16. A 33-year-old male with no past medical history presents for diffuse, mild abdominal pain. He is alert and in no acute distress, and his vital signs are within normal limits. He is mildly tender to his RUQ and epigastrium, so you decide to perform a RUQ ultrasound, shown in Figure 7.10 and Video 7.7.

Figure 7.10

What is the cause of this finding?

A. A congenital fold in the gallbladder fundus
B. A junctional fold in the gallbladder body
C. Cholangiocarcinoma
D. A septation in the gallbladder

17. A 32-year-old female presents with RUQ abdominal pain, nausea, and vomiting after eating nachos. She is afebrile and appears in no discomfort. She has mild

epigastric and RUQ tenderness, without guarding or rebound. You perform the ultrasound scan shown in Figure 7.11 and Video 7.8.

Figure 7.11

What is your next step in management?

A. Call surgery for emergent consultation
B. Consider alternate etiologies for the patient's abdominal pain
C. Outpatient referral to surgery
D. Admit to hospital for IV antibiotics

18. You are seeing a 50-year-old male with upper abdominal pain. He has a history of liver disease, but you want to make sure that he does not have cholelithiasis or cholecystitis. Which of the following locations in Figure 7.12 should you measure the gallbladder wall?

Figure 7.12

A.
B.
C.
D.

19. A 25-year-old pregnant woman comes in with upper abdominal pain. You perform a RUQ ultrasound to evaluate for biliary disease and obtain the ultrasound shown in Figure 7.13 and Video 7.9, which show a gallbladder wall thickness of 5 mm.

Figure 7.13

Which is the most likely reason for this finding?

A. Acute cholecystitis
B. Liver disease
C. Contracted gallbladder
D. Gallbladder mass

20. Which of the following conditions are associated with a thickened gallbladder wall?

A. Alcoholic hepatitis
B. Ascites
C. Cholecystitis
D. All of the above

21. A 76-year-old male with a history of diabetes is brought in by emergency medical services after altered mental status and abdominal pain. His wife called to report that her husband had complained for worsening abdominal pain for several days. The patient is febrile to 39.0°C and tachycardic to 112 bpm (or beats per minute) and appears disoriented. He groans with rebound tenderness with abdominal palpation. You perform the ultrasound shown in Figure 7.14 and Video 7.10.

What is your diagnosis?

A. Cholelithiasis
B. Uncomplicated cholecystitis
C. Emphysematous cholecystitis
D. Acalculous cholecystitis

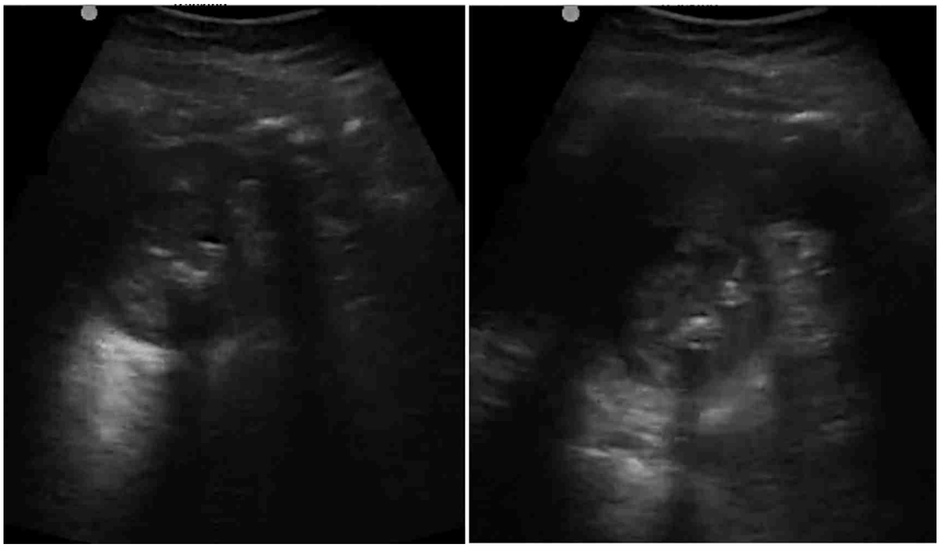

Figure 7.14

22. **A 23-year-old female veterinarian student presents with worsening abdominal pain and jaundice for the past 3 weeks. Of note, she studied abroad in India 6 months ago, working with livestock in rice fields. On exam, she has scleral icterus and mild abdominal tenderness but otherwise appears well. She has eosinophilia, with a direct bilirubin of 5.0 mg/dl, and alkaline phosphatase of 300 IU/L. You perform the RUQ ultrasound shown in Figure 7.15.**

Figure 7.15 Adapted from Figure 34.2b of Pua BB, Covey AM, Madoff DC, eds. *Interventional Radiology: Fundamentals of Clinical Practice.* New York, NY: Oxford University Press; 2018;452–460.

What is your likely diagnosis?

A. Cholangitis
B. Gallstones
C. Parasitic infection
D. Cholangiocarcinoma

23. **A 39-year-old female presents with worsening of her biliary colic for the past day. Usually, the pain subsides after about 2 hours and with use of her pain medication. However, she has had the pain for over 10 hours, along with nausea and vomiting. You perform the ultrasound shown in Figure 7.16 and Video 7.11.**

Figure 7.16

Which of the following is *not* true?

A. A Sonographic Murphy Sign confirms acute cholecystitis.
B. Gallstones may not be present in acute cholecystitis.
C. Pericholecystic fluid is a less common finding in acute cholecystitis.
D. A ring-down artifact from gas in the gallbladder wall may obscure gallbladder contents in cholecystitis.

24. **The image in Figure 7.17 and Video 7.12 was obtained from a 25-year-old female who presented to the ED with 1 week of postprandial epigastric pain. Her surgical history includes laparoscopic cholecystectomy 5 years ago.**

Which of the following is *not* true?

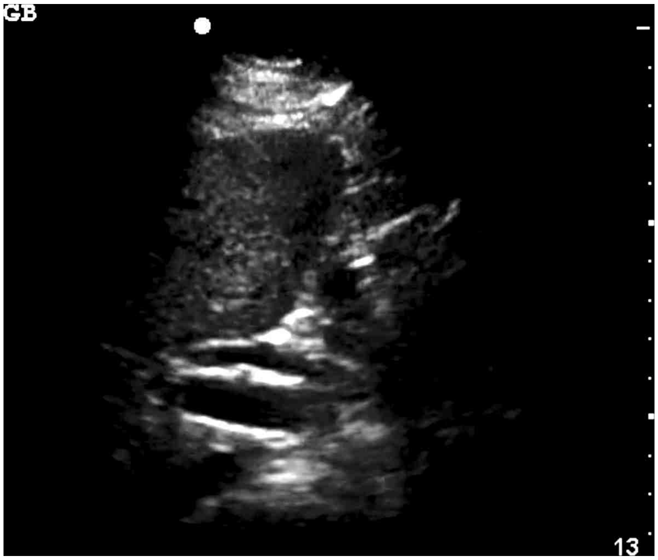

Figure 7.17

A. This patient's CBD measurement is expected to be less than 6 mm.
B. The CBD should be measured from inner wall to inner wall.
C. A dilated CBD lacks color flow.
D. All of the above.

25. **A patient is diagnosed with symptomatic choledocholithiasis in the ED. What is the next step in the management of this patient?**

A. MRCP
B. ERCP
C. Endoscopic ultrasound
D. Antibiotics and cholecystectomy

26. **A 36-year-old female presents with epigastric and RUQ pain with nausea and vomiting 30 minutes after eating fried chicken. She has had similar pain in the past after eating fried foods. Her vital signs are 110/76 mmHg, 18 breaths/min, heart rate 99 beats/min, and temperature 37.5 degrees Celsius. She has tenderness in her epigastric area and RUQ. You perform a RUQ ultrasound (Figure 7.18). The patient also has a negative Sonographic murphy sign.**

You initiate treatment with IV antiemetics, pain medication, and IV fluids, and her symptoms resolve.

Figure 7.18

What is the next step in management?

A. Consult general surgery for cholecystectomy.
B. Administer IV antibiotics.
C. Discharge the patient with outpatient referral to general surgery.
D. Admit the patient for overnight observation.

27. **Which of the following can make the gallbladder difficult to visualize sonographically?**

A. Porcelain gallbladder
B. Wall-echo-shadow sign
C. Gallbladder neoplasm
D. All of the above

28. **A 44-year-old male presents with fever, jaundice, and RUQ pain. His abdominal ultrasound confirms the diagnosis of Mirizzi syndrome. What sonographic signs do you expect to find in Mirizzi syndrome?**

A. Dilatation of the biliary system above the level of the gallbladder neck
B. The presence of a stone impacted in the gallbladder neck
C. An abrupt change to a normal diameter of the common duct below the level of the stone
D. All of the above

29. **A 57-year-old woman presents to the emergency department with epigastric abdominal pain that is crampy and severe for 6 hours. She reports being nauseous but has not vomited. She recently underwent an ERCP procedure for suspected choledocholithiasis. Physical examination reveals a woman in moderate abdominal distress. Vital signs are as follows: temperature 97.5°F, blood pressure 147/75 mm Hg, heart rate 88 beats/min, respiratory rate 19 breaths/min. The abdomen is tender in the epigastric area. There is no**

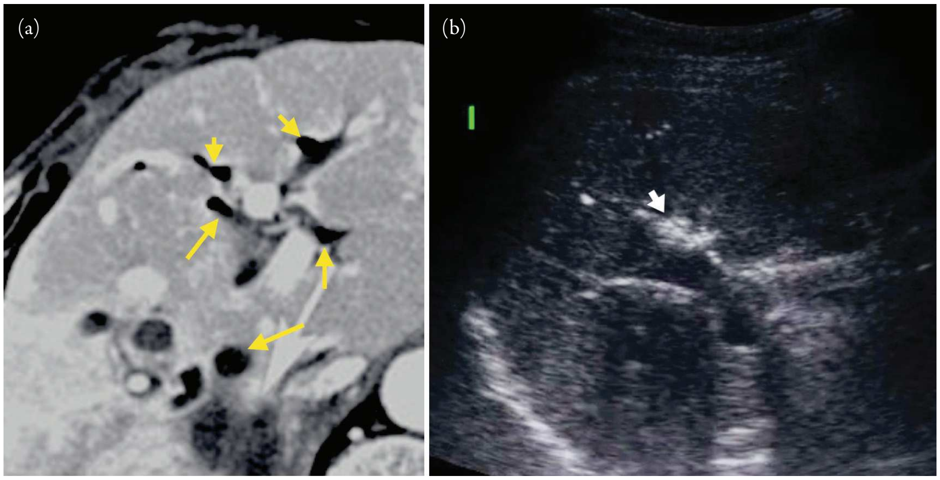

Figure 7.19 From Figure 75.4, Kim SY et al. Cholangitis. In: Levy AD, Mortele KJ, Yeh BJ, eds. *Gastrointestinal Imaging*. Oxford, UK: Oxford University Press; 2015.

rebound and bowel sounds were normal. A CT is shown in Figure 7.19a. You perform an ultrasound of her gallbladder (Figure 7.19b). What are common causes for this finding?

A. Recent biliary instrumentation
B. Incompetent sphincter of Oddi
C. Biliary-enteric surgical anastomosis
D. All of the above

30. A 46-year-old male presents to the ED with nausea, vomiting, RUQ pain, and jaundice. His past medical history is significant for a cholecystectomy performed 8 years ago. You perform a point-of-care RUQ ultrasound, shown in Figure 7.20.

What is the diagnosis?

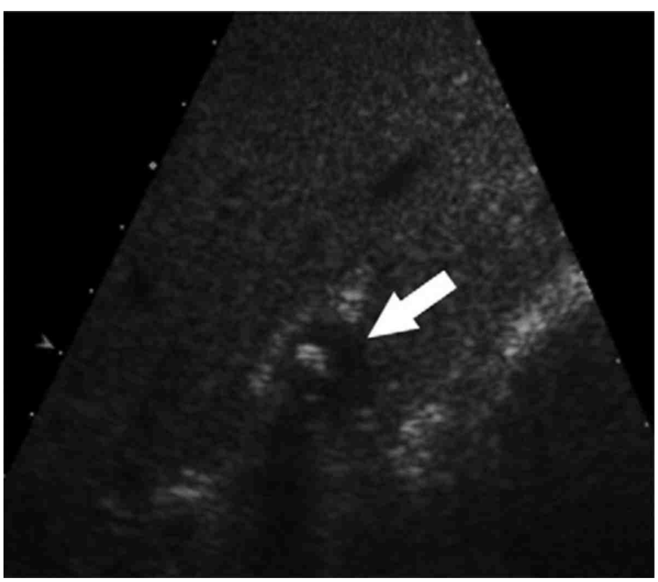

Figure 7.20

A. Pancreatitis
B. Small bowel obstruction
C. Incomplete cholecystectomy with retained gallstones
D. Liver cancer

31. A 21-year-old female with cystic fibrosis (CF) is admitted with acute onset RUQ pain, nausea, and vomiting. She denies any oral intake for the past 12 hours. Physical exam reveals moderate RUQ tenderness and rebound. Laboratory values are significant for an elevated white blood cell count with bandemia and an elevated alkaline phosphate level. You perform a RUQ ultrasound, shown in Figure 7.21.

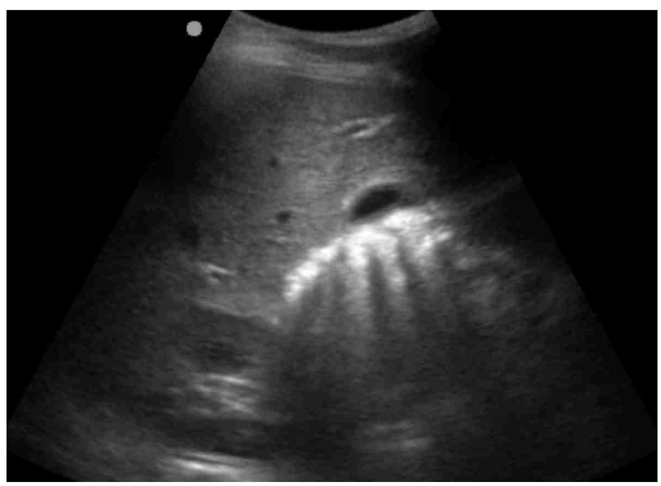

Figure 7.21

Her ultrasound findings are likely due to which of the following?

A. Emphysematous cholecystitis
B. Inspissated mucus associated with her CF

C. Insufficient fasting time of 12 hours
D. Chronic cholecystitis

32. A 55-year-old female presents with fevers, chills, and RUQ pain. Her vital signs are significant for a temperature of 38.7°C and tachycardia to 122 beats per minute. She has a leukocytosis of 24K, and her lactate is elevated at 4 mmol/L. You perform a point-of-care ultrasound, shown in Figure 7.22 and Video 7.14.

Figure 7.22

When discussing her diagnosis and prognosis with her, which of the following statements should be included?

A. You have simple acute cholecystitis and will require a laparoscopic surgical procedure.
B. You have choledocholithiasis and will require a procedure called endoscopic retrograde cholangiopancreatography.
C. You have an infection of your gallbladder and will require admission, antibiotics, and emergent surgery.
D. You do not have gallbladder disease, and we will have to obtain further imaging tests.

33. A 52-year-old male presents with epigastric and RUQ pain, with nausea and vomiting. His vital signs are unremarkable, and his laboratory workup is significant for an elevated lipase level suggestive of acute pancreatitis. A point-of-care ultrasound of his RUQ is performed for further evaluation, and the image shown in Figure 7.23 and Video 7.15 is obtained.

Turning the patient to his left lateral decubitus position does not change the image or findings. What abnormality is likely found on his gallbladder ultrasound?

A. Cholelithiasis
B. Gallbladder polyps
C. Gallbladder sludge
D. Acute cholecystitis

Figure 7.23

34. A 62-year-old female with a history of arterial hypertension, ischemic cardiomyopathy, and chronic severe aortic regurgitation was admitted to the intensive care unit with hemodynamic instability expressed as tachycardia and arterial hypotension; fever (38.7°C), abdominal pain, and vomiting lasting 1 day; and altered mental status. On examination, the patient was obtunded, pale, and with a poor peripheral perfusion. A tense and tender mass was found in the RUQ. A point-of-care ultrasound was performed as shown in Figure 7.24 and Video 7.16. A white blood count of 13,000 per mm3 (80% neutrophils) was the remarkable data on laboratory tests. The diagnosis of acute acalculous cholecystitis was made based on clinical and sonographic findings.

Figure 7.24

Which of the following interventions would be most appropriate?

A. Parental antibiotics without surgical planning
B. Percutaneous cholecystostomy to aid in stabilizing patient
C. Immediate open cholecystectomy
D. Surgical intervention is not an option for this patient

35. A 67-year-old-male who works as a postal service supervisor presents with epigastric pain, nausea and jaundice. He reports his abdominal pain and nausea have progressed over months but noticed the jaundice over the past 2 days. His vital signs were within normal limits. Clinical examination reveals a jaundiced patient, with a nontender abdominal exam. Laboratory tests find a normal white blood count, mild anemic, and elevated alkaline phosphatase (ALP) as well as direct bilirubin. A point-of-care ultrasound is performed and is shown in Figure 7.25 and Video 7.17.

Figure 7.25

What is his likely diagnosis?

A. Acute cholecystitis
B. Acalculous cholecystitis
C. Cholangiocarcinoma (CC)
D. Acute hepatitis

36. A 43-year-old obese female presents with burning diffuse abdominal pain after eating a hamburger and French fries. She has mild epigastric tenderness but otherwise appears well and in no acute distress. You order a gastrointestinal cocktail and perform the RUQ ultrasound shown in Figure 7.26.

What is your next best step?

A. Order a confirmatory RUQ ultrasound
B. Rotate the transducer to obtain a transverse axis
C. Consult surgery
D. Discharge the patient

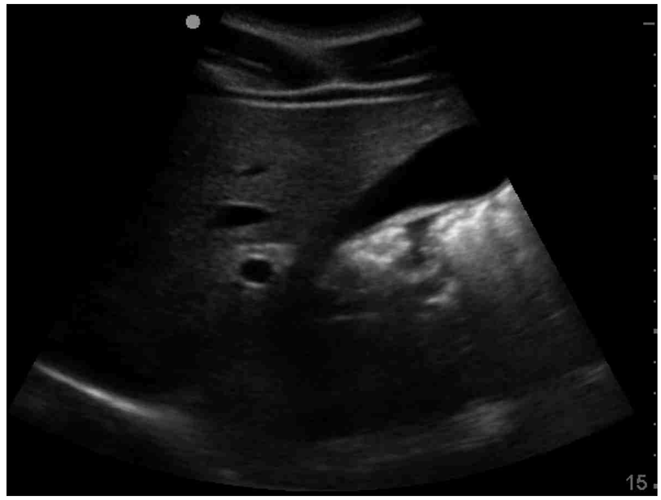

Figure 7.26

37. A 58-year-old woman presents with suprapubic pain and dysuria. She appears well and has a benign abdominal exam. Her urinalysis shows she has a urinary tract infection. Prior to discharge, a medical student on his ultrasound rotation performs a RUQ ultrasound for educational purposes. He shows you the ultrasound shown in Figure 7.27.

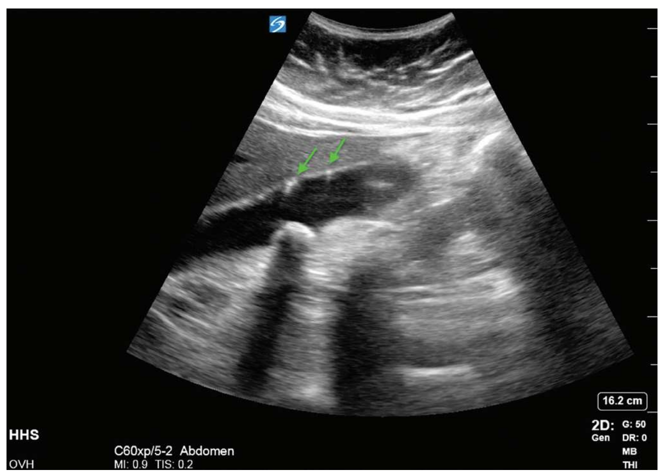

Figure 7.27

What is his likely diagnosis?

A. Acute cholecystitis
B. Acalculous cholecystitis
C. Cholangiocarcinoma
D. Adenomyomatosis

38. A 27-year-old male presents with fever, nausea, and RUQ pain for the past week. He had traveled to Cambodia last month and, upon returning, had a violent episode of bloody diarrhea for about 3 days before it

cleared spontaneously. Since then, he has had recurrent fevers and chills, with increasing abdominal pain. On exam, he is febrile and tachycardic, with tenderness to his RUQ. You perform the ultrasound shown in Figure 7.28 and Video 7.18.

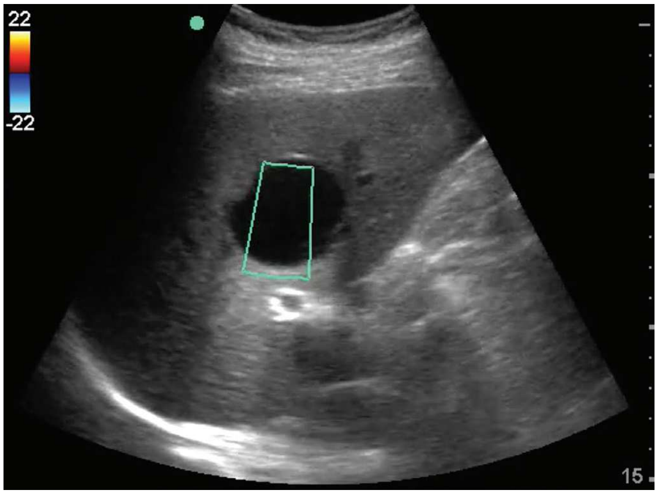

Figure 7.28

What is his likely diagnosis?

A. Acute cholecystitis
B. Hepatocellular carcinoma
C. Liver abscess
D. Acute hepatitis

39. A 58-year-old female presents with worsening abdominal and back pain for the past 2 months. Her daughter is concerned that she has become more "yellow" over the past week. On exam, she has frank jaundice, and there is mild tenderness to her epigastrium. You perform the RUQ ultrasound shown in Figure 7.29 and find a heterogeneous mass (*).

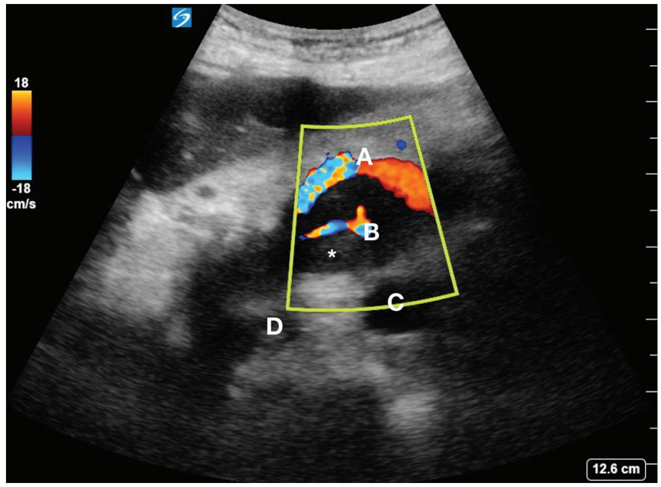

Figure 7.29

What are the surrounding structures?

A. A. aorta, B. IVC, C. celiac trunk, D. portal vein
B. A. portal vein, B. celiac trunk, C. aorta, D. IVC
C. A. portal vein, B. celiac trunk, C. IVC, D. aorta
D. A. celiac trunk, B. portal vein, C. aorta, D. IVC

ANSWERS

1. EXPLANATION

A. The portal triad and median lobar fissure (MLF). The main portal triad generally lies posterior and medial to the gallbladder in the sagittal plane. The MLF can be found as a hyperechoic line that extends from the neck of the gallbladder toward the main portal vein. This is also known as the "exclamation point sign." The gallbladder serves as the top portion of the exclamation point, and the portal vein serves as the dot at the bottom, connected by the MLF (Figure 7.30). Of note, the MLF has no anatomical basis but is a sonographic sign. Its echogenicity is likely due to the fibrous connective tissue in the gallbladder fossa. Its closest anatomical equivalent is Cantlie's line, after the Irish surgeon who first described a line that can be drawn from the gallbladder fossa to the IVC posteriorly, which divides the right and left segments of the liver.

Learning Points: The portal triad and the median lobar fissure (MLF) are important landmarks to identify when locating the gallbladder.

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Keywords/Tags: Gallbladder, hepatobiliary, interpretation

2. EXPLANATION

D. All of the above. The presence of stones in the gallbladder in the clinical setting of RUQ abdominal pain and fever supports the diagnosis of acute cholecystitis. Additional sonographic features include

1. Gallbladder wall thickening >3 mm.
2. Pericholecystic free fluid.
3. A positive SMS.

A SMS is similar to the Murphy's sign elicited during abdominal palpation, except that the positive response is observed during palpation with the ultrasound transducer. This is more accurate than physical exam as it ensures palpation directly over the gallbladder by the transducer.

Learning Points: Sonographic findings of acute cholecystitis such as gallbladder wall thickness greater than 3 mm, pericholecystic fluid, gallstones, and presence of a sonographic Murphy's sign (SMS) in the right clinical scenario should prompt acute surgical consult for intervention.

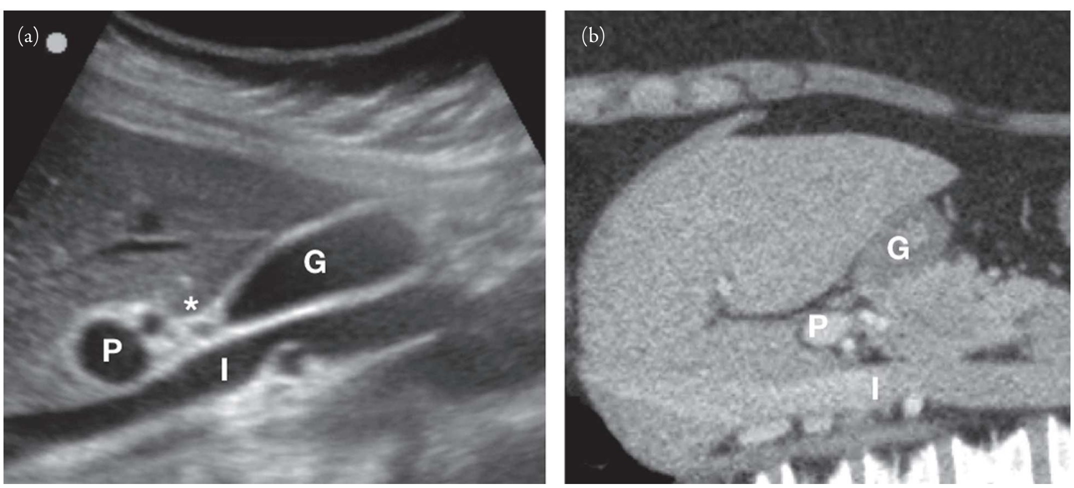

Figure 7.30 **Main lobar fissure and portal vein.** Panel (a) shows a sagittal view of the gallbladder (G) in long axis, with the fundus, body and neck orientation pointing towards the portal vein (P). Together, this forms the "exclamation point" sonographic sign. The main or median lobar fissure is the hyperechoic linear structure (*) commonly seen that links these two structures. Note that the inferior vena cava (I) lies just posterior to the portal vein. Cantlie's line, which is not seen in this cross section, is the closest anatomical version of the median lobar fissure. It can be traced from the main hepatic vein as it connects with the inferior vena cava and the gallbladder fossa. Cantlie's line divides the right and left hepatic segments. For comparison, Panel (b) shows a sagittal view on CT of the gallbladder, portal vein, and IVC. *Images provided by Alan Chiem and Olive View–UCLA Medical Center.*

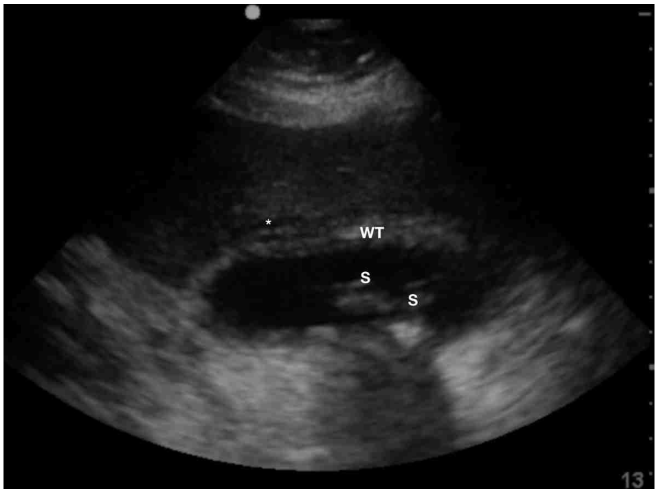

Figure 7.31 **Acute cholecystitis.** This is a long axis view of a gallbladder containing stones (S), an irregular thickened wall (WT), and pericholecystic fluid (*). These sonographic signs, along with a positive sonographic Murphy sign, suggest acute cholecystitis.

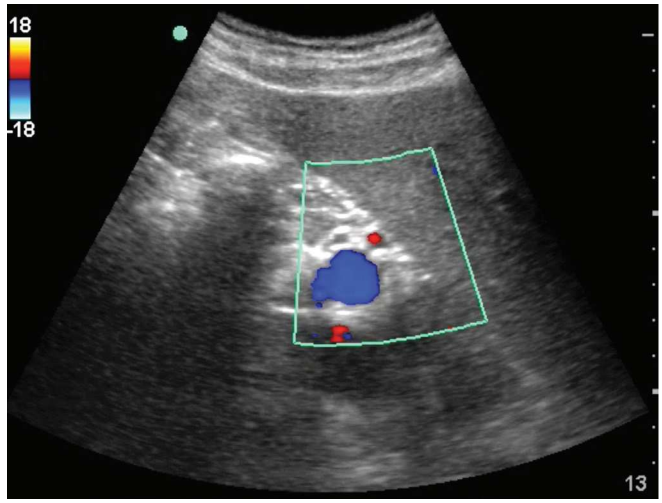

Figure 7.32 **Mickey Mouse sign with color Doppler.** This is a short axis image of the portal triad, with the main portal vein representing the head, and the hepatic artery demonstrating flow in the top right. The biliary duct is thus on the top left, as it has no flow. Note that the hepatic artery rarely dilates, so if there is asymmetry in one of the "ears," it is typically due to biliary duct dilation.

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Keywords/Tags: Acute cholecystitis, sonographic Murphy's sign, pericholecystic fluid

3. EXPLANATION

D. Portal vein (1), CBD (2), hepatic artery (3). The largest structure in the portal triad is the portal vein. The two smaller structures are the CBD and the hepatic artery. In this long-axis view of the gallbladder, the portal triad takes the appearance of Mickey Mouse, with the CBD and hepatic artery making up the ears and the portal vein as the head. The CBD is typically represented by Mickey's right ear, or to the left on the screen. Color Doppler can be utilized to differentiate the CBD from the two vascular structures, as seen in Figure 7.32.

Learning Points: The portal triad consists of the portal vein, hepatic artery, and CBD. Color Doppler can be used to differentiate the hepatic artery from the bile duct.

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Keywords/Tags: Gallbladder, hepatobiliary, interpretation

4. EXPLANATION

A. His CBD can be normal for someone of his age. Traditional teaching is that the normal size of the CBD is 6 mm or less in a patient 60 years of age or younger. For every 10 years over 60, add 1 mm, so a 70-year-old can have 7 mm, an 80-year-old 8 mm, and so on. The CBD measurement of 9 mm may be normal for a 90-year-old male. However, some studies do suggest some variability to CBD size in the elderly. Perret (2000) showed that the mean CBD diameter for patients older than 85 years of age was still under 5 mm. Furthermore, each institution may have its own cut-off values. In addition, multiple studies have demonstrated that the size of the CBD increases after cholecystectomy and can be as large as 1 cm.

Learning Points: The normal size of the CBD is 6 mm or less in a patient 60 years of age or younger. It can dilate 1 mm for every decade after age 60. The CBD also dilates after cholecystectomy.

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Keywords/Tags: Gallbladder, hepatobiliary, interpretation

5. EXPLANATION

B. His CBD is measured correctly and is of normal size for his age. The CBD is measured from inside to inside (Figure 7.33), in contrast to measurements such as the abdominal aorta, which is measured outside to outside. In the first documented use of early gray-scale ultrasound machines to identify hepatobiliary disease, Perlmutter (1976) and Behan (1978) note that inner wall to inner wall diameter best correlated with intravenous (IV) cholangiography. In addition, the resolution of these machines made it difficult to discern the outer borders of the CBD from surrounding liver tissue. These two reasons are the historical basis for measuring the CBD inner wall to inner wall. Interestingly, many of the common techniques employed today for gallbladder evaluation are described in these works, such as the relationship of the CBD to the portal vein, inspiratory pause, and lateral decubitus positioning.

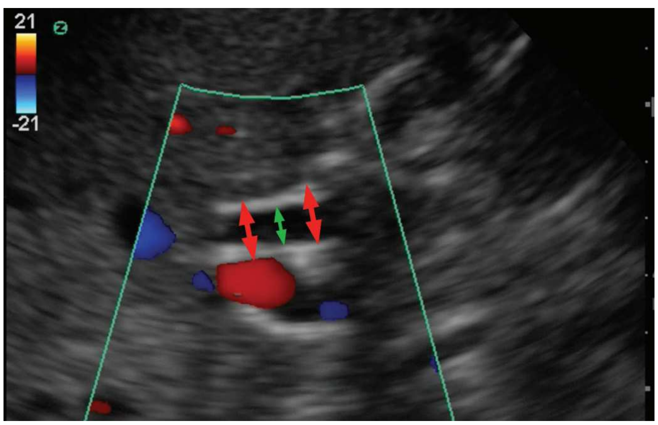

Figure 7.33 **CBD measurements.** The red arrows show incorrect measurements as they measure the outer wall-to-outer wall and outer wall-to-inner wall diameters. The correct measurement is inner wall-to-inner wall, as shown by the green arrows.

Learning Points: The CBD should be measured from inside wall to inside wall.

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Keywords/Tags: Gallbladder, hepatobiliary, interpretation

6. EXPLANATION

D. Low-frequency probe, subcostal region, medial to lateral. The low-frequency probe should be used as it allows for assessment of deeper abdominal organs. Although both an intercostal (at mid-clavicular and anterior axillary line) and subcostal location can be chosen, the approach involves an assessment of the region in a medial to lateral technique while flattening and fanning the probe for a complete regional assessment. This is termed a subcostal sweep (see Figure 7.34, Video 7.19). Since there are normal anatomic variations of gallbladder location in the RUQ, this

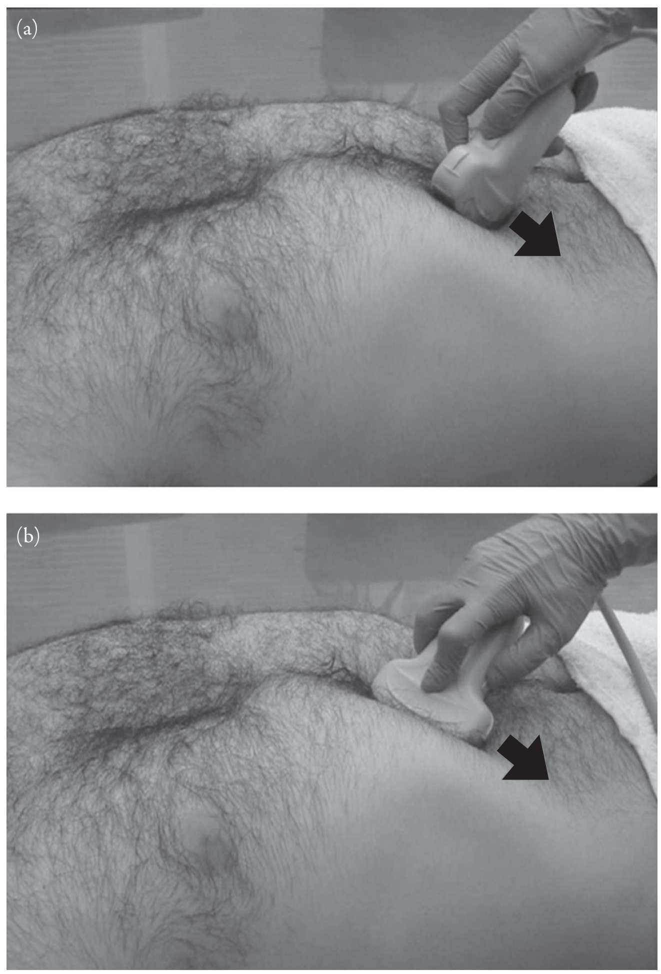

Figure 7.34 **Subcostal sweep.** A low frequency transducer is placed just inferior to the costal margin and near the xiphoid process. The sonographer can then methodically slide and fan/tilt the transducer laterally to assess for hepatobiliary pathology. The maneuver can be performed in both sagittal (a) and axial (b) planes.

technique helps to identify the gallbladder as well as thoroughly assesses the liver.

Learning Points: A subcostal sweep, using a low-frequency probe placed in the right subcostal region, can evaluate hepatobiliary pathology by sliding medial to lateral.

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Keywords/Tags: Gallbladder, hepatobiliary, RUQ, right upper quadrant, subcostal sweep

7. EXPLANATION

C. Epigastric and RUQ pain. Fever, vomiting, and headache are nonspecific symptoms that can be related to many different disease processes. Of those listed, RUQ pain is most correlative to hepatobiliary pathology. Patients with epigastric, RUQ, and right flank pain should get a hepatobiliary ultrasound scan, while the pain being combined with other nonspecific symptoms such as nausea, vomiting, and fever can help increase clinical suspicion. If jaundice occurs, then a hepatic and obstructive biliary pathology should be considered (Figure 7.35). Fever, abdominal pain, and jaundice comprise the classic Charcot's triad for acute cholangitis. The additional presence of altered mental status and hypotension (known as Reynold's pentad) signifies acute suppurative cholangitis and is an endoscopic emergency. The Tokyo Guidelines, first introduced in 2007 and subsequently revised in 2018, can be used to integrate physical exam, imaging, and laboratory findings to assess severity of acute cholangitis.

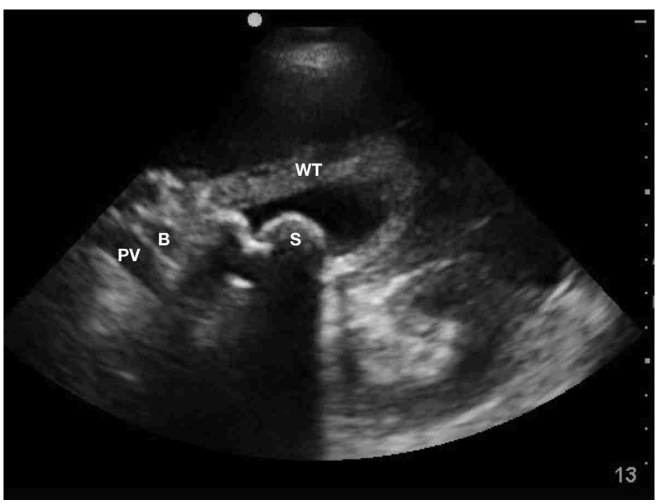

Figure 7.35 **Choledocholithiasis on ultrasound.** This is an oblique long axis view of the gallbladder. Note the presence of a gallstone (S), an irregularly thickened gallbladder wall (WT), as well as biliary duct dilation (B). The portal vein (PV) is seen just posterior to the duct. Note that the sonographic findings must be integrated with clinical and laboratory findings to diagnose cholangitis.

Learning Points: Jaundiced patients with epigastric, RUQ, and right flank pain with other nonspecific symptoms such as nausea, vomiting, and fever, should receive a hepatobiliary POCUS exam.

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Keywords/Tags: Right upper quadrant pain, hepatobiliary, RUQ, cholecystitis, gallstone

8. EXPLANATION

D. All of the above. Placing the patient on his or her left lateral decubitus position will move bowel toward the patient's left side, away from the gallbladder, displacing the gas scatter artifact that obstructs the image. It also can push the gallbladder closer to the abdominal wall. Deep patient inspiration will lower the gallbladder closer to your subcostal probe, which can help to visualize it. In addition, bending the patient's knees will relax the abdominal wall musculature, allowing you to apply the needed pressure in the subcostal region for RUQ assessment. If the subcostal region cannot be used due to patient discomfort or a protuberant abdomen, then the probe can be placed on the chest wall between the ribs at 7 or 12 cm lateral to the xiphoid process (Figure 7.36). The locations are the mid-clavicular and anterior axillary line, respectively. These are the areas where the gallbladder is thought most commonly to reside.

Learning Points: Patient positioning to improve hepatobiliary imaging include: placing the patient on his or her left lateral decubitus position, performing an inspiratory pause, and bending their knees.

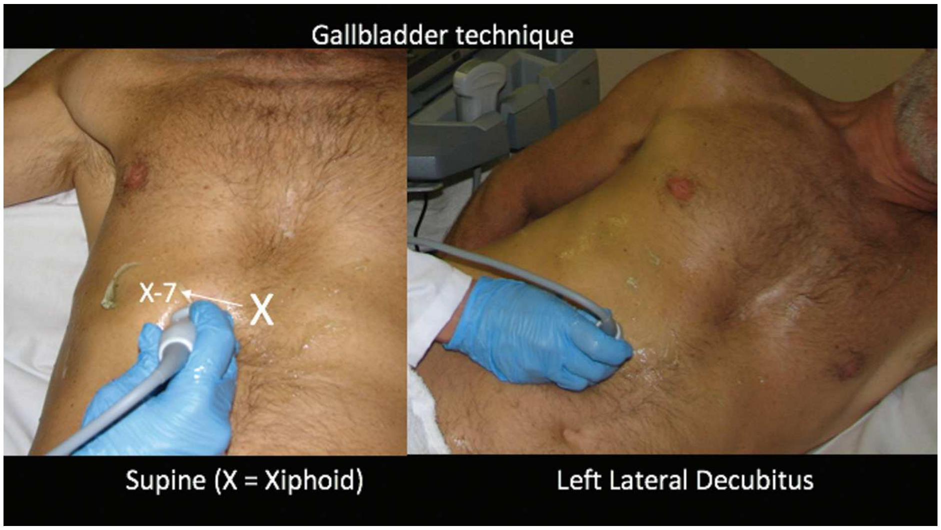

Figure 7.36 **Tips for visualizing the gallbladder.** Intercostal approaches like the X-7 technique or imaging from the axillary lines can help to reduce bowel gas interface, by imaging through the liver and to the gallbladder. In addition, inspiratory pause drops the diaphragm, allowing more use of the liver as an acoustic window (not shown). Flexing the knees also relaxes the abdominal muscles, and allows for more compression of bowel (not shown). Lastly, positioning the patient in a left lateral decubitus or semiprone position displaces bowel and allows for better visualization of the gallbladder.

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Keywords/Tags: X minus 7, X minus 12, RUQ, right upper quadrant pain, gallstone, gas scatter

9. EXPLANATION

D. Wide fanning through the gallbladder in 2 orthogonal planes. After performing a subcostal sweep with the low-frequency probe using B-mode, a cystic-like structure can be correctly identified as the gallbladder by also ensuring an absence of color Doppler flow, which will prevent the IVC from being mistakenly identified as the gallbladder. The gallbladder should then be centered on the screen and at the screen's focal point. Wide fanning through both the transverse and longitudinal planes of the gallbladder can assess for biliary pathology as one view may have limitations in visualization that the other view will not. For example, bowel gas artifact from the adjacent duodenum can mimic a gallstone. This artifact usually appears within the lumen of the gallbladder in one axis but appears outside the lumen in an orthogonal axis (Figure 7.37).

Learning Points: Fanning through the gallbladder in two orthogonal planes will help to avoid bowel gas artifact. Using color Doppler will also help to differentiate adjacent vascular structures from the gallbladder.

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Keywords/Tags: Gallbladder, fanning, technique, RUQ, right upper quadrant

10. EXPLANATION

D. Scan with patient in lateral decubitus positioning. When a stone is identified in the neck with wide fanning through the gallbladder, the patient should be turned on to his or her left lateral decubitus side to assess for stone mobility. A stone that is immobile increases the risk of impending cholecystitis. Inspiration by the patient and assessing the gallbladder through the ribs improves the ability to find the gallbladder but does not help in assessing risk for cholecystitis. By evaluating the gallbladder in transverse plane, the

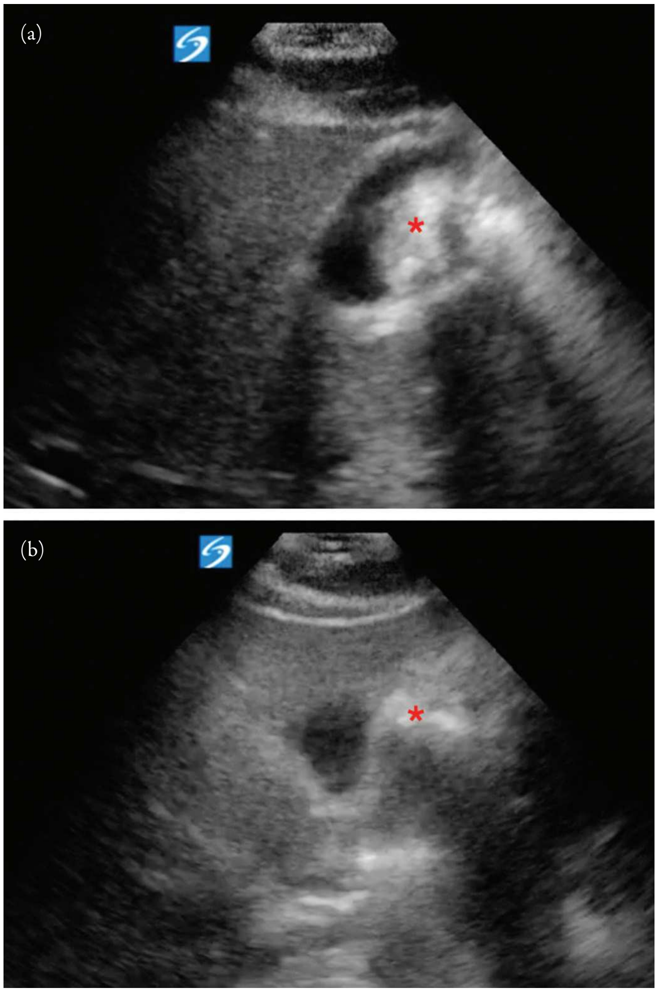

Figure 7.37 **Bowel gas mimicking gallstones.** In the long axis image of the gallbladder (Panel (a)), there appears to be ill-defined hyperechoic area displaying shadowing. This collection of bowel gas from the adjacent duodenal can easily be mistaken for gallstones. However, on the short axis image, the same collection is seen to be outside the lumen of the gallbladder, thereby confirming that it is bowel gas. This underlies the importance of imaging in two orthogonal planes, especially when confronted with a potential pathology like gallstones. Please compare the panels in Figure 7.10 to see the transducer orientation in orthogonal planes.

stone at the neck and its accompanying shadow artifact can be differentiated from edge artifact.

Learning Points: Careful evaluation of the gallstone neck should be performed to assess for gallstones in the neck. When present, assessing for stone mobility by changing patient positioning is required for proper gallstone assessment since an immobile gallstone at the neck is a sign of impending cholecystitis.

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Keywords/Tags: Gallstone in neck, stone in neck, SIN, right upper quadrant

11. EXPLANATION

A. Apply pressure with the probe over the visualized gallbladder. By applying pressure over the visualized gallbladder with the probe, and eliciting pain, the specificity and positive predictive value for diagnosing cholecystitis increases when gallstones are visualized. In several studies, the SMS in the presence of gallstones is associated with an 80% to 90% specificity and a 90% positive predictive value for acute cholecystitis. A SMS is considered positive if a patient has focal pain upon pressure of the transducer on the gallbladder. This is different from a clinical Murphy's sign on physical exam where the clinician's hand is pressed in the RUQ and a patient is asked to take a deep breath in. If the patient stops breathing mid-breath secondary to pain, that is considered a positive clinical Murphy's sign. It is particularly important that the SMS is assessed by the clinician at the initial patient encounter, since premedication decreases the utility of the SMS. Although color Doppler may be helpful in diagnosing acute cholecystitis, pulsed wave Doppler has not been well studied. Turning the patient on his or her left side will improve visualization of the gallbladder and is useful when there is a large gallstone in the neck. However, this patient has multiple stones but none in the neck. M-mode is not used during gallbladder scanning.

Learning Points: A SMS is elicited pain upon probe palpation of the visualized gallbladder on the screen and, when combined with identified gallstones, contributes to a higher specificity and positive predictive value for the diagnosis of acute cholecystitis.

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Keywords/Tags: Sonographic Murphy's sign, right upper quadrant pain, gallstone, cholecystitis

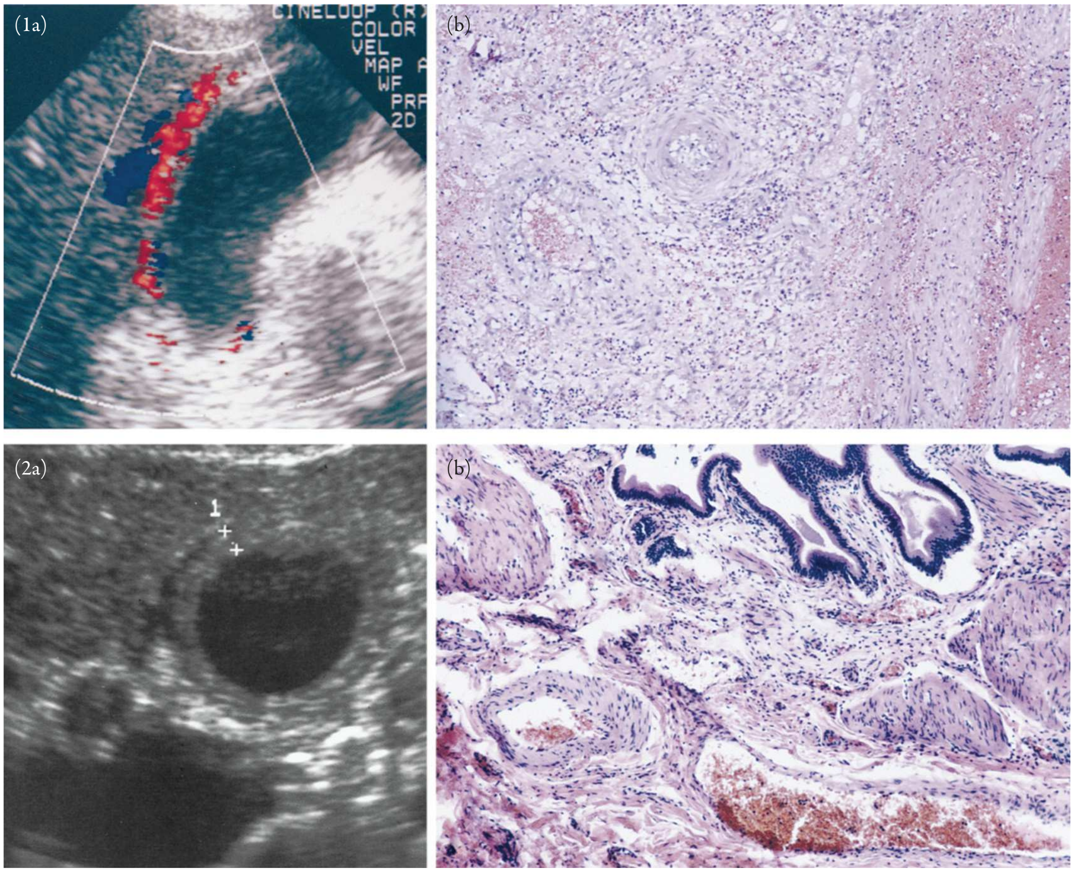

Figure 7.38 **Use of Color Doppler to differentiate acute from chronic cholecystitis.** Hyperemia is present in the gallbladder wall with acute cholecystitis. This is demonstrated as increased flow using color power Doppler (CPD) on ultrasound and in microscopy of the wall in Panels 1a and 1b, respectively. Hyperemia and inflammation are mild or not present in chronic cholecystitis, in which the wall is thickened due to fibrosis from recurrent bouts of biliary colic-induced ischemia. In Panels 2a and 2b, there is no flow on CPD and no evidence of diffuse inflammation on microscopy. Adapted from: Schiller VL, Turner RR, Sarti DA. Color Doppler imaging of the gallbladder wall in acute cholecystitis: sonographic-pathologic correlation. *Abdom Imaging.* 1996;21(3):233–237.

12. EXPLANATION

D. All of the above. Pericholecystic fluid can be a sign of acute inflammation, especially in the presence of an irregular gallbladder wall. However, like gallbladder wall thickening, it is nonspecific and can be associated with systemic causes like liver disease, congestive hepatopathy, and renal failure. A positive SMS can also suggest acute cholecystitis but can also occur with biliary colic and chronic cholecystitis. Assessing for hypervascularity or inflammation of the gallbladder wall can be performed using color power Doppler. Since recurrent bouts of wall ischemia from biliary colic can lead to recurrent inflammation and subsequent fibrosis of the gallbladder wall, patients with chronic cholecystitis may present with wall thickening. Color power Doppler can help to differentiate acute from chronic cholecystitis by the presence of hypervascularity of the wall (Figure 7.38).

Learning Points: Color Doppler may be used to assess for acute cholecystitis, especially when there is presence of wall thickening.

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Keywords/Tags: Acute cholecystitis, chronic cholecystitis, color Doppler

13. EXPLANATION

D. Place patient in left lateral decubitus, indicator toward patient's right, and scan in the subcostal region. The best patient position is left lateral decubitus due to displacement of bowel gas scatter away from the gallbladder, with the indicator toward either the patient's head or

the right side in the subcostal region. Alternatively, one can place the transducer on the right flank, but not the left posterior-axillary line (see Figure 7.36).

Learning Points: When bowel gas obscures the gallbladder, placing patients in left lateral decubitus and scanning in the right subcostal region can improve visualization.

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Keywords/Tags: Patient position, cholecystitis, right upper quadrant, RUQ, technique

14. EXPLANATION

A. A congenital fold in the gallbladder fundus. This is called a Phrygian cap, which is a congenital folding of a portion of the fundus, which is present in Phrygian cap about 2% to 6% of the population (Figure 7.39). It appears as a septation, but true septations in the gallbladder are very rare. Phrygian caps have no clinical significance, and thus further evaluation should be conducted to assess the etiology of the patient's pain. This is not the classic appearance for sludge or cholangiocarcinoma.

Learning Points: A Phrygian cap is a congenital fold of the fundus that appears to be a septation on ultrasound. It has no clinical significance.

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Keywords/Tags: Phrygian cap, gallbladder anatomy, congenital

15. EXPLANATION

D. All of the above. The gallbladder is attached to the inferior surface of the liver via the loose connective tissue of the visceral peritoneum. From fundus to neck, the gallbladder sits typically in an inferior-superior to superior-posterior position. The fundus often lies more anterior and inferior than the inferior liver margin. The neck is less mobile due to its relationship to the portal triad, which is found within the hepatoduodenal ligament that binds the duodenum to the liver. The gallbladder body and fundus are relatively more mobile and can change position due to mass effect from adjacent organs like the ascending colon and duodenum, or body positioning. As a result of its variable position, many techniques must be employed to image the gallbladder, from subcostal to anterior or axillary intercostal spaces (Figure 7.40). The use of a phased array transducer, which has a much smaller footprint than a curvilinear transducer, may be helpful to minimize rib-shadowing artifact.

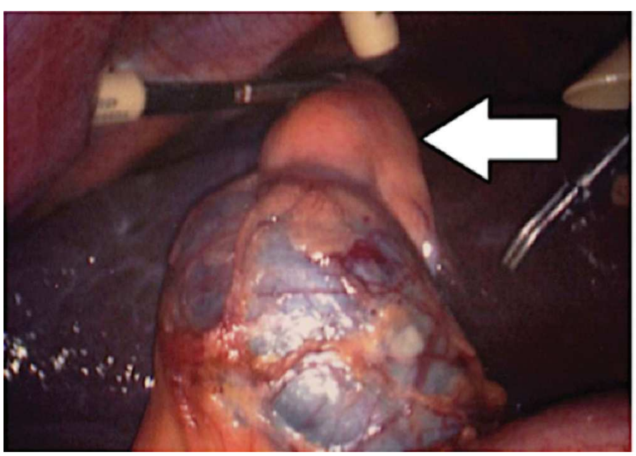

Figure 7.39 **Phrygian cap of gallbladder and statue.** The image on the left shows a Phrygian cap, a congenital folding of the fundus. The image on the right shows a statue of Attis, a local deity in ancient Phrygia, in what is modern day Turkey, wearing the customary cap. Phrygian caps of the gallbladder occur in about 2% to 6% of the population and have no clinical significance. They may, however, be mistaken for a gallbladder mass or septation. Adapted from Figures 3 and 5 of Al-Ashqar M, Maliyakkal AK, Shiwani MH, Anwar S. Acalculous Phrygian cap cholecystitis. *BMJ Case Rep*. 2013. doi:10.1136/bcr-2013-009921.

(a)

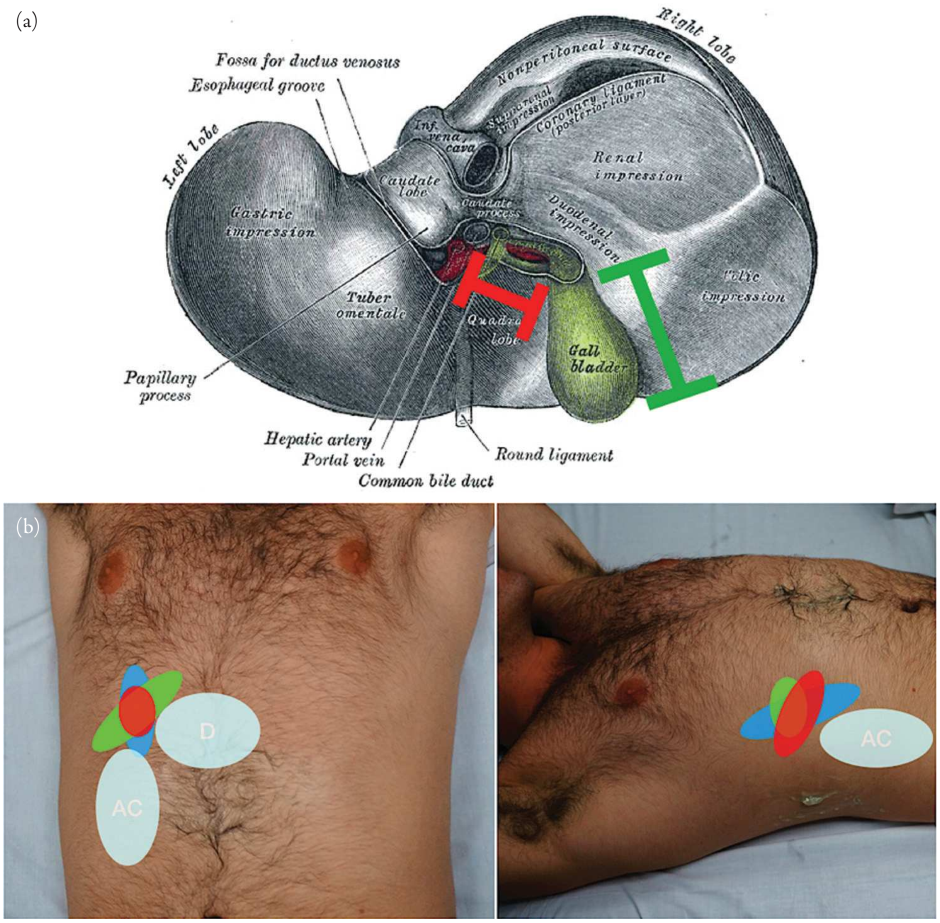

Figure 7.40 (a) **Anatomy of gallbladder and mobility.** This view of the liver is from a posterior-to-anterior vantage point. The gallbladder neck and infundibulum (indicated by red bars) lie in the gallbladder fossa, which is where the porta hepatitis and portal triad are also found. These structures are held together by the hepatoduodenal ligament, rendering the proximal gallbladder relatively less mobile. In contrast, the body and fundus (indicated by green bars) are surrounded by loose connective tissue of the visceral peritoneum, and are relatively more mobile. Adapted from Figure 1086 of Gray H. *Anatomy of the Human Body.* New York, NY: Lea & Febiger; 1918. (b) **Variable position of gallbladder.** The gallbladder is a highly mobile organ, with its positioning due to the anatomy of the gallbladder fossa in the liver, mass effect from adjacent duodenum (D) and ascending colon (AC), and patient positioning. There are, however, some common orientations to note. In blue, the gallbladder, from fundus to neck, is in an inferior-to-superior orientation. In green, it is in a lateral-to-medial orientation, and in red, it is largely anterior to posterior. Recognizing these common orientations will help the sonographer to develop a three dimensional sense of the gallbladder that is necessary for ultrasound imaging.

Learning Points: The relationship of the gallbladder to the surface anatomy is highly variable. Sonographers must learn to identify and distinguish the gallbladder's longitudinal and transverse axes from the surface anatomy.

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Keywords/Tags: Hepatoduodenal ligament, liver, peritoneum, mobility

16. EXPLANATION

B. A junctional fold in the gallbladder body. This is called a junctional fold, which occurs typically in the body of the gallbladder. More commonly it is seen in the posterior wall, as the anterior wall is attached to the posterior surface of the liver via connective tissue. Unlike Phrygian caps or septations, junctional folds are usually transient and may resolve with gallbladder distension or patient positioning. Like Phrygian caps, there is no clinical significance of junctional folds, but they may be mistaken for polyps. To

diagnose true septations, they must be seen in both longitudinal and transverse planes. Cholangiocarcinoma can present as intraluminal masses or irregularity of the wall and biliary duct, but not typically as a fold.

Learning Points: Junctional fold.

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Keywords/Tags: Junctional fold, gallbladder anatomy, Phrygian cap, septation

17. EXPLANATION

B. Consider alternate etiologies for the patient's pain. This patient has a normal RUQ ultrasound. The normal gallbladder wall (W) measures less than 3 mm when measured anteriorly against the liver. With a normal gallbladder wall and no gallstones, there is no evidence of cholecystitis or cholelithiasis and alternate sources of pain should be considered. In addition, the biliary duct (B) is seen in long axis just anterior to the main portal vein (PV). The main portal vein is typically 10 mm in diameter, so if the biliary duct appears less than half that diameter, it is unlikely to be dilated.

Learning Points: The normal thickness of the gallbladder wall is less than 3 mm.

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Keywords/Tags: Gallbladder, hepatobiliary, interpretation

18. EXPLANATION

A. The gallbladder wall should be measured at the near (anterior) wall against the liver, preferably in short axis view at its most narrow point. Measuring the gallbladder posteriorly can result in a false measurement due to posterior acoustic enhancement created from bowel and gas artifact. Interestingly, while this is referred to as the "anterior wall," in a coronal cross-section of the gallbladder, the appropriate wall to measure is the lateral wall. Therefore, the closest wall to the top of the screen should be measured, to avoid posterior acoustic enhancement of the deeper wall.

Learning Points: The gallbladder wall should be measured at the near (anterior) wall against the liver.

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Keywords/Tags: Gallbladder, hepatobiliary, interpretation

19. EXPLANATION

C. Contracted gallbladder. The normal gallbladder may be contracted. The layers of the gallbladder wall from outside to inside are the serosa, perimuscular fibrous tissue, smooth muscle muscularis, lamina propria, and epithelium. Normally, these layers are indistinguishable by ultrasound imaging. When cholecystokinin is released from the duodenum in response to a fatty meal, the muscularis contracts, giving a thickened 3-layer appearance to the wall. The inner and outer walls are echogenic while the middle layer is hypoechoic. Also, due to contraction and expulsion of bile, the transverse lumen of the contracted gallbladder is usually less than 1 cm.

Acute hepatitis may also lead to a narrow lumen gallbladder, possibly due to decreased bile secretion into the gallbladder. However, the wall is usually thin. In addition, other systemic diseases can cause a thickened wall, but the transverse lumen diameter is >1 cm.

Learning Points: A contracted gallbladder will have a narrow transverse lumen (<1 cm) and striated, thickened wall. Typically this is seen about 1 to 3 hours postprandial, but clinical correlation is warranted.

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Keywords/Tags: Gallbladder, hepatobiliary, interpretation

20. EXPLANATION

D. All of the above. Ninety-two percent of patients with acute cholecystitis have a thickened gallbladder wall (greater than 3 mm). However, a variety of other conditions are also associated with a thickened gallbladder wall, such as alcoholic hepatitis, ascites, congestive heart failure, renal failure, HIV/AIDS, and pancreatitis. This is due to hepatic venous congestion that leads to increased portal vein pressure and decreased venous draining and edema to the gallbladder wall. Therefore while gallbladder wall thickness is a relatively sensitive indicator of acute cholecystitis, it is not a specific finding. In the right clinical context, though, gallbladder wall thickening may suggest acalculous cholecystitis.

Figure 7.41 **Nonspecific gallbladder wall thickening associated with congestive hepatopathy.**

Learning Points: Gallbladder wall thickening is not specific for cholecystitis and can be seen in many systemic diseases.

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Keywords/Tags: Hepatobiliary, wall thickening, systemic disease, acalculous cholecystitis

21. EXPLANATION

C. Emphysematous cholecystitis. Although gallstones are more common in women and cholecystitis is predominantly a complication of gallstone disease, emphysematous cholecystitis is more common in men. Infection of the gallbladder with anaerobic, gas-forming species, like Clostridium, leads to air in the lumen and/or wall. Emphysematous cholecystitis is a surgical emergency, as patients have high morbidity and mortality compared to acute cholecystitis. For example, there is a 5-fold association with gangrenous cholecystitis, in which the gallbladder becomes necrotic and easily ruptures. Major risk factors for emphysematous cholecystitis are diabetes and male sex.

On ultrasound, air "dirty shadowing" artifact may be seen both in the gallbladder wall as well as the lumen. The clinician should suspect emphysematous cholecystitis if the gallbladder appears hazy or "effervescent," as this could signal air. A plain radiograph may help to confirm the diagnosis by showing radiolucent outlining of the gallbladder and expedite emergent surgical intervention.

Learning Points: Suspect emphysematous cholecystitis in ill-appearing patients with air "dirty shadowing" artifact emanating from the wall or within the gallbladder lumen.

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Keywords/Tags: Hepatobiliary, emphysematous cholecystitis, air shadowing, clostridium

23. EXPLANATION

C. Parasitic infection. This patient has a typical presentation for parasitic infection of the biliary tree. Mainly these are caused by the "flukes" or trematodes, such as *Fasciolopsis, Clonorchis, Opisthorchis*, and *Schistosomiasis species*. A common exposure is to freshwater, where the flukes mature. They can be ingested via improperly washed plants, improperly cooked meat or fish, or through direct skin penetration. Many of these infections are asymptomatic or indolent, and the presentation

is often delayed, when there is sign of biliary obstruction. On ultrasound, the findings in the gallbladder are nonspecific, with usually some sludge or other echogenic material. The intrahepatic biliary ducts, however, often appear very dilated.

Although cholangitis and cholangiocarcinoma may be associated with these infections, the patient is not ill appearing to suggest cholangitis. Cholangiocarcinoma may be a late complication of these infections but is not suggested in this case.

Learning Points: Serious pathology may be mistaken for gallbladder sludge.

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Keywords/Tags: Gallbladder sludge, parasitic infections

23. EXPLANATION

A. A SMS confirms acute cholecystitis. In patients with cholelithiasis, additional sonographic findings consistent with acute cholecystitis may include a thickened gallbladder wall, pericholecystic fluid, or the presence of a SMS. No single sonographic sign is sensitive or specific enough to make the diagnosis of acute cholecystitis alone, and a small number of patients have no sonographic evidence of hepatobiliary disease at all. A thickened gallbladder wall (>3 mm) is seen in about 92% of patients with acute cholecystitis. However, this finding is also seen in a number of other conditions, including chronic cholecystitis, and is not specific for acute cholecystitis. Pericholecystic fluid is a less common finding but is more specific for cholecystitis in the absence of other etiologies such as congestive heart failure or ascites (Figure 7.42). The SMS is positive when the point of maximal tenderness elicited by the pressure of the ultrasound transducer occurs directly over the sonographically identified gallbladder; less tenderness should be elicited when the transducer pressure is directed in areas other than the gallbladder. Acalculous cholecystitis accounts for approximately 10% of acute cholecystitis cases and is associated with a higher morbidity and mortality. Emphysematous cholecystitis is a less common variant of cholecystitis caused by a secondary infection of the gallbladder with gas-forming bacteria. Ring-down or air shadowing artifact can be seen in cases of emphysematous cholecystitis (Table 7.1).

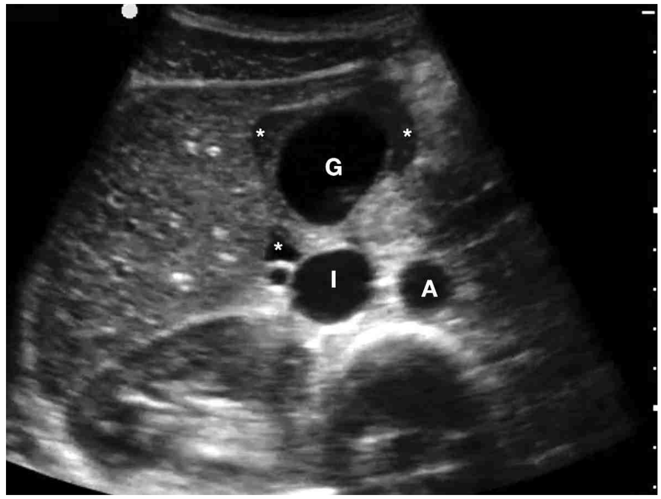

Figure 7.42 **Peri-cholecystic fluid and wall edema.** This is a transverse view of the gallbladder as well as the patient's abdomen. The gallbladder appears round, with both wall edema and peri-cholecystic fluid (*). Note the inferior vena cava (I) and aorta (A) below in short axis as well.

Table 7.1. DISEASES OF THE GALLBLADDER

TYPE	DISEASE
Calculous disease	Gallstones, gallstone ileus, Mirizzi syndrome
Inflammation	Cholecystitis (acute, complicated, chronic), porcelain gallbladder
Infection	Empyema (suppurative cholecystitis), emphysematous cholecystitis, gangrenous cholecystitis, mucocele
Neoplasia	Benign (adenomyomatosis, lipoma, etc.), carcinoma, metastatic (pancreatic, gastric, renal, ovarian, melanoma)
Iatrogenic disease	Postcholecystectomy (abscess, hematoma, bile leak)
Trauma	Perforation, torsion

Adapted from Table 7.1, O'Connor OJ, Maher MM. Imaging of cholecystitis. *AJR*. 2011;196:W367–W74.

Learning Points: No single sonographic finding is sufficient to confirm acute cholecystitis.

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Keywords/Tags: Hepatobiliary, cholecystitis

24. EXPLANATION

A. This patient's CBD measurement is expected to be less than 6 mm. The CBD may dilate when obstructed by a stone, mass, or stricture. The normal adult CBD measures less than 4 mm from inner wall to inner wall and may increase in size up to an additional 1 mm for each decade beyond 50 years of age. After cholecystectomy, the CBD may also dilate up to 10 mm. This is seen as the "double barrel shotgun" or "tram track" sign, which is a dilated CBD that appears above and parallel to the portal vein. Of note, 80% to 90% of patients after cholecystectomy do not have more than 2 mm of CBD dilation. Therefore, a significantly dilated CBD and presence of symptoms should alert the clinician to the possibility of a retained gallstone.

Learning Points: The CBD may normally dilate up to 10 mm after cholecystectomy. A dilated CBD can be seen as a "double barrel shotgun" sign.

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Keywords/Tags: Hepatobiliary, common bile duct, cholecystectomy, retained stone

25. EXPLANATION

B. ERCP. The next step in the management of a patient that has been diagnosed with the presence of a CBD stone (choledocholithiasis) is ERCP. If the diagnosis of choledocholithiasis remains in question after abdominal ultrasound, management may include MRCP, endoscopic ultrasound, or ERCP based on the patient's risk for having choledocholithiasis. Antibiotics and cholecystectomy are the management of choice for acute cholecystitis.

Learning Points: The next step in management when a patient is diagnosed with choledocholithiasis is endoscopic retrograde cholangiopancreatography (ERCP).

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Keywords/Tags: Hepatobiliary, choledocholithiasis

26. EXPLANATION

C. Discharge the patient with outpatient referral to general surgery. This patient has biliary colic with

Table 7.2. MEAN CBD DIAMETER ASSOCIATED WITH AGE AND CHOLECYSTECTOMY STATUS

AGE RANGE (YEARS)	NUMBER IN STUDY	INTACT GALLBLADDER, MEAN CBD DIAMETER ± SD (MM)	POSTCHOLECYSTECTOMY, MEAN CBD DIAMETER ± SD (MM)
18–49	164	4.4 ± 1.2	5.1 ± 1.8
50–59	113	4.9 ± 1.6	5.8 ± 1.5
60–69	118	5.4 ± 1.6	6.6 ± 2.0
70–79	169	5.7 ± 1.7	6.6 ± 1.7
>80	83	6.0 ± 1.6	9.6 ± 0.7

Note. CBD = common bile duct; SD = standard deviation.

Adapted from Tables 7.1 and 7.2, Benjaminov F, Leichtman G, Naftali T, et al. Effects of age and cholecystectomy on common bile duct diameter as measured by endoscopic ultrasonography. *Surg Endosc*. 2013;27:303–307.

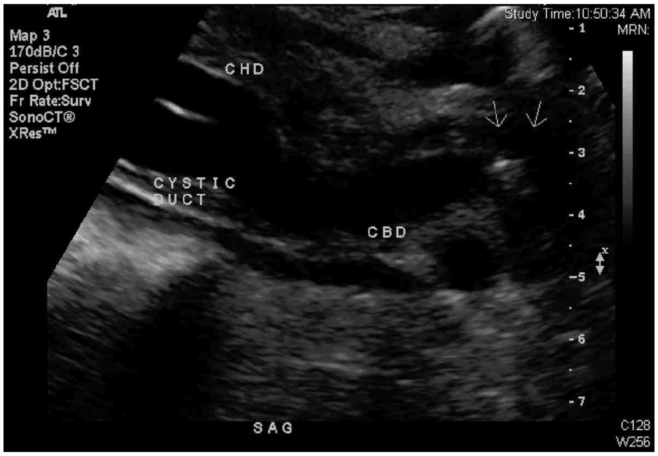

Figure 7.43 **Choledocholithiasis on endoscopic ultrasound.** This endoscopic ultrasound image shows a gallstone (arrows) in the common bile duct. The common hepatic duct (CHD) and cystic duct are seen to the left. Note that the CBD diameter is roughly 10 mm.

cholelithiasis without signs of acute cholecystitis on ultrasound. Sonographic signs of acute cholecystitis include SMS, pericholecystic fluid, and thickened anterior gallbladder wall. Cholelithiasis without evidence of acute cholecystitis and symptomatic control in the ED is appropriate for outpatient consult and surgical planning with general surgery.

Learning Points: Cholelithiasis without acute cholecystitis findings should be managed with symptomatic care and outpatient referral to general surgery.

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Keywords/Tags: Cholelithiasis, sonographic signs of acute cholecystitis, sonographic Murphy sign

27. EXPLANATION

D. All of the above. Porcelain gallbladder is a rare condition that results in an increased risk of carcinoma. The calcification and subsequent shadowing make a porcelain gallbladder difficult to examine with ultrasound. The wall-echo-shadow sign represents gallstones filling the lumen of a contracted or incompletely visualized gallbladder so that only the gallbladder wall, a thin hypoechoic space of bile, and the hyperechoic line of gallstones with the subsequent acoustic shadow are visible in the gallbladder fossa (Figures 7.44 and 7.45). Gallbladder neoplasms can have a variable appearance on ultrasound; neoplasms may cause focal gallbladder wall thickening or may appear as a mass in the gallbladder. At times a gallbladder mass may fill the entire lumen of the gallbladder, making it difficult to distinguish from the surrounding hepatic tissue. Emphysematous cholecystitis causes a ring-down artifact from the gas in the gallbladder wall, which may also make interrogation of the gallbladder difficult. Postprandial contraction of the gallbladder also makes the gallbladder more difficult to localize, especially for novice sonographers. Awareness of all these conditions and familiarity with their sonographic appearances are important for anyone performing hepatobiliary ultrasound so that the gallbladder is not confused with air-filled loops of bowel or other surrounding structures.

Learning Points: There are several conditions that may make sonographic examination of the gallbladder difficult.

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Keywords/Tags: Porcelain gallbladder, wall-echo-shadow sign, emphysematous cholecystitis

28. EXPLANATION

D. All of the above. Mirizzi syndrome should be suspected in any patients with RUQ pain, jaundice, and fever. Mirizzi syndrome is a gallstone in the neck or cystic duct that causes extrinsic compression of the CBD or common hepatic duct, leading to jaundice and potential for cholangitis, as well as ductal dilation proximal to the compression (Figure 7.46). Cholecystectomies are complicated by Mirizzi syndrome due to the difficulty in dissection and separation of the cystic artery and cystic duct, as well as complications associated with cholecystobiliary fistulas. The diagnosis of Mirizzi syndrome requires the presence of the following on abdominal imaging (e.g., transabdominal ultrasonography, contrast-enhanced computed tomography [CT], MRCP):

- Dilatation of the biliary system above the level of the gallbladder neck.
- The presence of a stone impacted in the gallbladder neck.
- An abrupt change to a normal diameter of the common duct below the level of the stone.

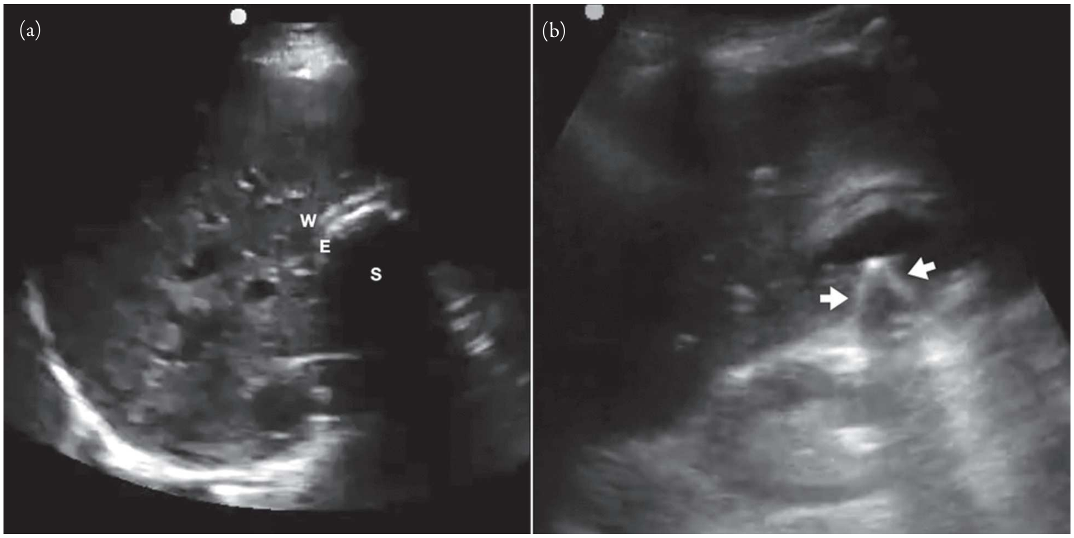

Figure 7.44 (a) **Wall-echo-shadow (WES) sign.** The anterior wall (W) is imaged, then the echogenic cortex of the gallstone (E), followed by the shadowing or attenuation artifact (S) caused by the stone. Typically, the WES sign is seen in a transverse view of the gallbladder, and due to either one large (>2cm diameter) stone, or several stones that fill the lumen completely. Note that rotation of the transducer by ninety degrees will lead the WES sign to give way to a traditional long axis view of the gallbladder. (b) **Emphysematous gallbladder.** In this image, there is ring-down artifact seen as two linear bands (arrows) emanating from the air pocket located within the lumen of the gallbladder. Emphysematous gallbladders may also display "dirty air shadowing" artifact as well as an "effervescent gallbladder," which shows an incompletely imaged lumen with scattering air molecules.

Learning Points: Mirizzi syndrome is an external compression of the extrahepatic bile duct by gallstones in the neck or cystic duct, leading to the cholangitis as well as surgical complications. Features suggestive of Mirizzi syndrome include (a) dilatation of the biliary system above the level of the gallbladder neck, (b) the presence of a stone impacted in the gallbladder neck, and (c) an abrupt change to a normal width of the common duct below the level of the stone.

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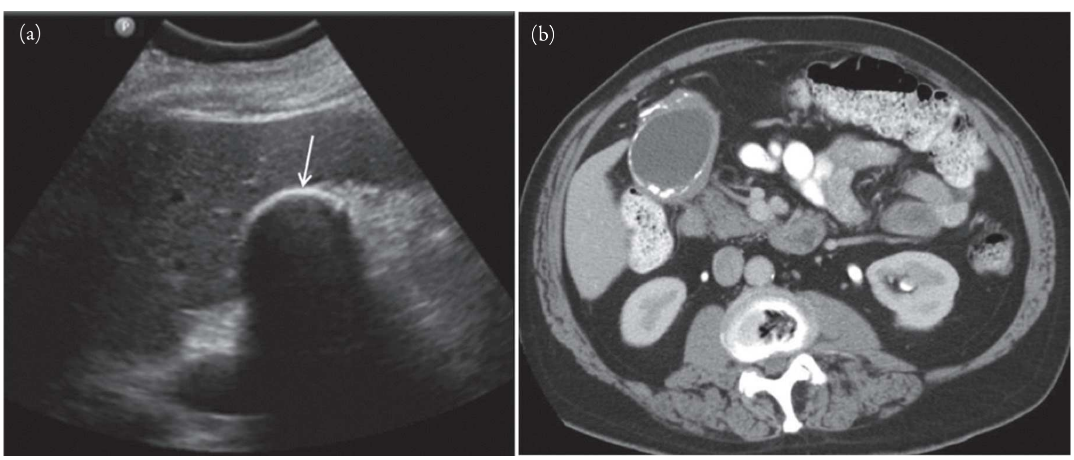

Figure 7.45 **Porcelain gallbladder.** In Panel (a), the gallbladder wall is calcified so that only the anterior segment is visualized as an echogenic rim (arrow), followed by the shadowing or attenuation artifact of the calcified wall. Panel (b) shows the calcified gallbladder wall on CT. Because there is a strong association with malignant transformation, patients with porcelain gallbladders should be referred to surgery for elective cholecystectomy. Adapted from Figure 4, Revzin MV et al. The gallbladder: uncommon gallbladder conditions and unusual presentations of the common gallbladder pathological processes. *Abdom Imaging.* 2015, 40:385–399.

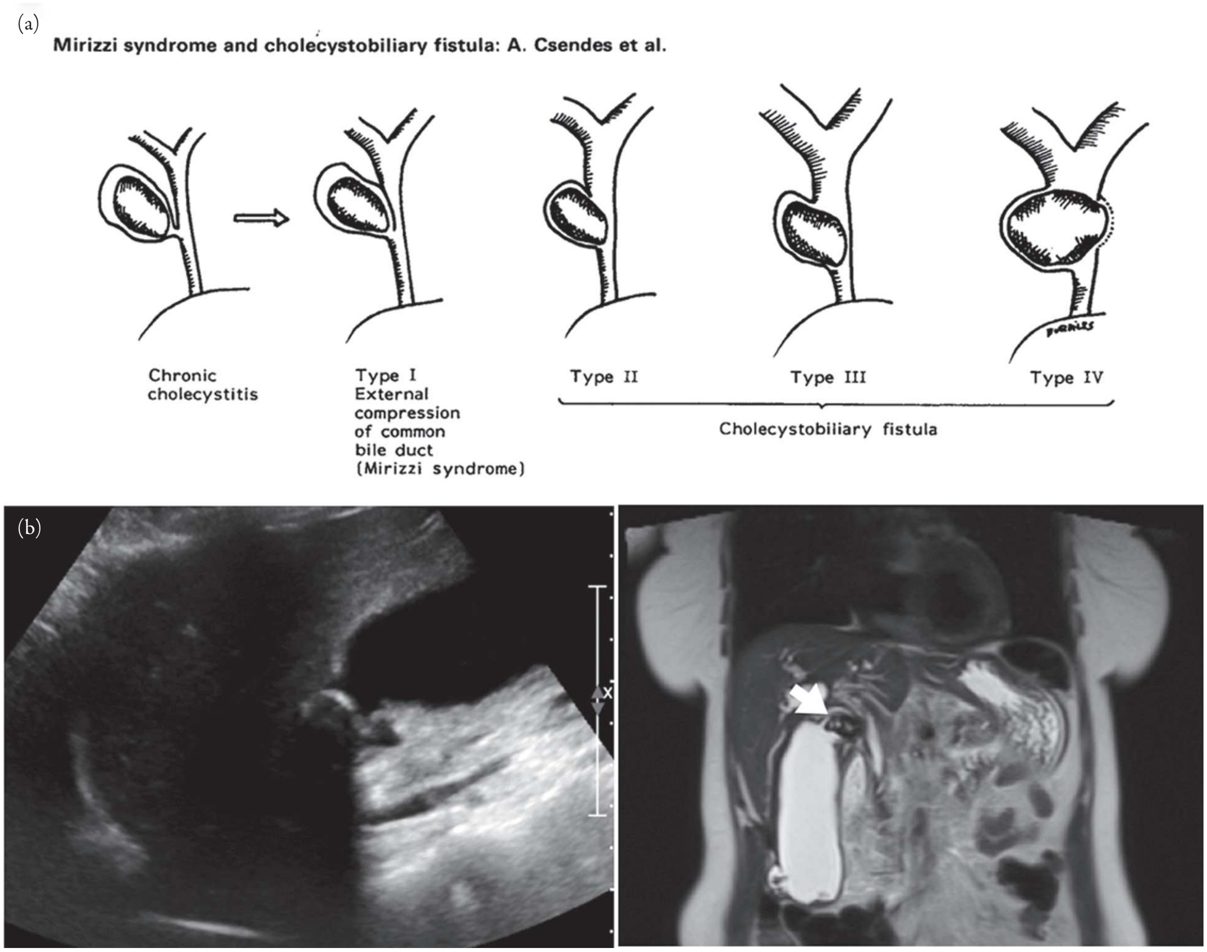

Figure 7.46 (a) **Mirizzi syndrome types.** The natural progression of Mirizzi syndrome begins with a gallstone in the neck or cystic duct. Recurrent episodes of outlet obstruction lead to chronic cholecystitis. This may lead to Mirizzi syndrome, which is external compression of the common hepatic or bile duct by a stone in the neck or cystic duct. As a result of recurrent inflammation and fibrosis, a cholecystobiliary fistula (CCBF) may form that forms a direct communication between the gallbladder and common bile duct (CBD). Grading of CCBFs are related to the severity of obstruction and destruction of the CBD, from 1/3 (Type II), 2/3 (Type III), and complete (Type IV) destruction and obstruction of the CBD. Adapted from Figure 1 of Csendes A, Díaz JC, Burdiles P, Maluenda F, Nava O. Mirizzi syndrome and cholecystobiliary fistula: a unifying classification. *Br J Surg.* 1989;76(11):1139–1143. (b) **Mirizzi syndrome on ultrasound and magnetic resonance cholangiopancreatography (MRCP).** In Panel (a), there is a large gallstone in the neck that, in the right clinical scenario (e.g., jaundice) would suggest Mirizzi syndrome. Note that ultrasound alone usually does not confirm the diagnosis. In Panel (b), MRCP shows a large gallstone in the neck that extrinsically compresses the common bile duct. *Images courtesy of Monica Deshmukh, MD, and Shaden Mohammad, MD, Olive View–UCLA Department of Radiology.*

Keywords/Tags: Mirizzi syndrome, cholecystobiliary fistula, cholangitis

29. EXPLANATION

D. All of the above. The ultrasound shows a gallbladder with pneumobilia. On plain film radiograph (A), air is seen as lucencies outlining the intrahepatic biliary tree. On ultrasound (B), air causes a dirty shadowing artifact that appears as indistinct hyperechoic shape with distal shadowing. This patient's history of recent ERCP or recent biliary instrumentation is the most likely (and a common) cause of pneumobilia. Ultrasound is very sensitive in detecting gas within the liver as it causes artifact, specifically regions of high echogenicity with prominent shadowing or reverberation. The liver has been described as having a "striped appearance." Common causes for pneumobilia include

- Recent biliary instrumentation (ERCP, percutaneous or intraoperative cholangiography).
- Incompetent sphincter of Oddi (sphincterotomy, following passage of a gallstone, scarring from diseases such as pancreatitis, drugs such as atropine, congenital).
- Biliary-enteric surgical anastomosis (e.g., cholecystoenterostomy, choledochoduodenostomy, Whipple procedure) or fistulas (biliary-duodenal or biliary-colonic).

Learning Points: The most common conditions associated with pneumobilia include (a) recent biliary instrumentation, (b) an incompetent sphincter of Oddi, (c) a biliary-enteric surgical anastomosis or fistulas.

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Keywords/Tags: Pneumobilia, choledochoduodenostomy, biliary-enteric fistula

30. EXPLANATION

C. Incomplete cholecystectomy with retained gallstones. Incidence of incomplete gallbladder removal following conventional cholecystectomy is rare. Reasons for incomplete resection include poor visualization of gallbladder fossa during surgery, adhesions, concurrent inflammation, excessive bleeding, or confounding gallbladder morphology. Stones are usually found in the remnant gallbladder or remnant cystic duct. The most common presentations are abdominal pain, fever, and jaundice. In most series, the primary diagnosis is established by ultrasound and/or CT scan (Figure 7.47). Retained stones are evident within 3 years after cholecystectomy versus recurrent stones, which are new stones in the CBD that are evident after 3 years of cholecystectomy.

Figure 7.47 **Remnant gallbladder with stone on CT.** Patients with a history of cholecystectomy may have a remnant gallbladder or cystic duct that can lead to stone development. This image shows a large stone (arrow) in a remnant gallbladder. Adapted from Figure 6 of Greenfield NP, Azziz AS, Jung AJ, Yeh BM, Aslam R, Coakley FV. Imaging late complications of cholecystectomy. Clin Imag. 2012;36(6):763–767.

Learning Points: Persistence of symptoms after cholecystectomy may be due to retained stones or regeneration of stones in the remnant gallbladder.

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Keywords/Tags: Remnant gallbladder, retained stone, incomplete cholecystectomy

31. EXPLANATION

B. Inspissated mucus associated with her CF. CF commonly affects the pancreas and liver, often leading to malabsorption as well as biliary cirrhosis (Figure 7.48). In the gallbladder, inspissated mucus leads to decreased bile secretion, and thus patients with CF may have microgallbladders, typically mistaken for contracted gallbladders. CF patients also can have gallbladder disease due to abnormal gallbladder function and absorption, with up to 24% with gallstones. If acute cholecystitis is considered in

Figure 7.48 **Pancreatic involvement in patients with cystic fibrosis.** More than 90% of cystic fibrosis patients have pancreatic involvement. The pancreas appears hyperechoic due to both decreased secretion as well as fibrosis, and multiple small pancreatic cysts can be seen. Burt H, Andronikou S, Langton-Hewer S. Pancreatic cystosis in cystic fibrosis. *BMJ Case Rep*. 2016; 2016:bcr2015214288.

a patient with CF, a gallbladder ultrasound should be performed for evaluation as well as biliary scintigraphy to evaluate the emptying of the cystic duct. However, clinicians should consider other etiologies that are associated with CF complications of the hepatobiliary system.

Learning Points: Cystic fibrosis is associated with an echogenic pancreas with or without cysts, biliary cirrhosis, as well as micro-gallbladder.

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Keywords/Tags: Cystic fibrosis, shrunken gallbladder, micro-gallbladder

32. EXPLANATION

C. You have an infection of your gallbladder and will require admission, antibiotics, and emergent surgery. Cholecystitis is inflammation of the gallbladder, which can lead to infections in the gallbladder. Empyema of the gallbladder, emphysematous cholecystitis, and gangrenous cholecystitis are infections of the gallbladder (Figure 7.49). Empyema of the gallbladder is usually the result of a progression of acute cholecystitis in a background of bile stasis and cystic duct obstruction. Prompt parenteral antibiotic therapy with urgent removal or drainage of the gallbladder should be the goal to prevent increased morbidity and the rare possibility of mortality. Surgeons who undertake a laparoscopic approach should have a low threshold to convert to open procedure when encountered with technical difficulties. The conversion rate from laparoscopic to open cholecystectomy is higher in empyema of the gallbladder than that in uncomplicated acute cholecystitis due to reduced visualization or distortion of the anatomical structures in Calot's triangle as well as increased bleeding due to inflamed friable tissue.

Learning Points: Ill-appearing patients with findings of severe acute cholecystitis (such as irregular wall thickening, gas, and sludge) may have gallbladder infections such as empyema or emphysematous cholecystitis.

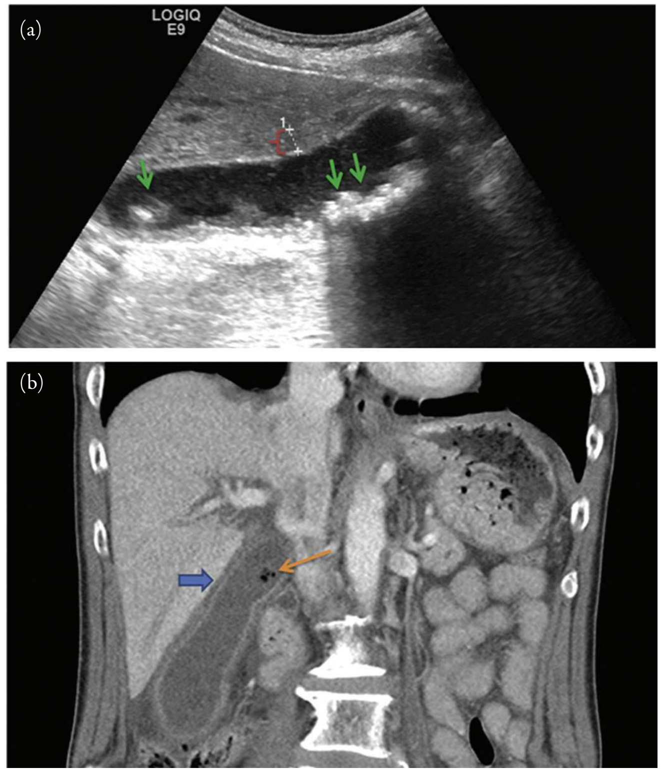

Figure 7.49 **Gallbladder empyema on ultrasound and computed tomography (CT).** Panel (a) shows a gallbladder ultrasound with typical signs of infection, including severely irregular wall thickening, stones, sludge, and air. The CT plane in Panel (b) shows a severely dilated gallbladder with surrounding pericholecystic fluid (blue arrow) and gas in the lumen of the gallbladder (orange arrow). Adapted from Figures 1 and 2 of Mehta V, Yarmish G, Greenstein J, Hahn B. Gallbladder empyema. *J Emerg Med*. 2016;50(6):893–894.

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Mehta V, Yarmish G, Greenstein J, Hahn B. Gallbladder empyema. *J Emerg Med*. 2016;50(6):893–894.

Keywords/Tags: Gallbladder empyema, open cholecystectomy, laparoscopic cholecystectomy

33. EXPLANATION

B. Gallbladder polyps. These are elevated lesions on the mucosal surface of the gallbladder. The vast majority are benign, but malignant entities are possible. They are best characterized on ultrasound. General features are a non-shadowing polypoid ingrowth into gallbladder lumen, which is usually immobile even with change of patient position unless there is a relatively long pedunculated component.

Management is based on presence of symptoms and size of polyp. Cholecystectomy should be considered if

1. The patient is symptomatic.
2. The polyp is ≥10 mm.
3. The polyp is <10 mm but there are high-risk features (age >50, solitary lesion, evidence of polyp growth over serial exams, presence of gallstones).

If the polyp is <10 mm and there are no high-risk features, patients should be referred for serial ultrasounds every 6 months.

Learning Points: Gallbladder polyps are a nonshadowing polypoid ingrowth into gallbladder lumen, which are usually immobile unless there is a relatively long pedunculated component.

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Keywords/Tags: Gallbladder polyps

34. EXPLANATION

B. Percutaneous cholecystostomy to aid in stabilizing patient. This is an image-guided placement of drainage catheter into gallbladder lumen. This minimally invasive procedure can aid stabilization of a patient to enable a more measured surgical approach with time for therapeutic planning. Other indications include poor surgical candidate/high-risk patients with acute calculous or acalculous cholecystitis, unexplained sepsis in critically ill patients, or access to or drainage of biliary tree following failed ERCP.

Acalculous cholecystitis on sonography typically is diagnosed by the triad of sludge, wall thickness >3.5 mm, and hydrops (long axis >8 cm or transverse axis >5 cm). However, Huffman and Schenker (2010) have published the following sonographic definition for acalculous cholecystitis: two of the following major criteria or one major plus the two minor criteria:

Major criteria: Wall thickness >3.5mm; pericholecystic fluid or subserosal edema; intramural gas; or sloughed mucosal membrane.

Minor criteria: Sludge or hydrops (as defined earlier).

Learning Points: Percutaneous cholecystostomy is a low-risk management option for high-risk patients with acute cholecystitis. It can be used as a temporizing measure while awaiting resolution of sepsis and optimization of comorbidities or as a definitive therapeutic option for acalculous cholecystitis.

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Nasim S, Khan S, Alvi R, Chaudhary M. Emerging indications for percutaneous cholecystostomy for the management of acute cholecystitis—a retrospective review. *Int J Surg*. 2011;9(6):456–459. doi:10.1016/j.ijsu.2011.04.008. PubMed PMID: 21679779.

Keywords/Tags: Acalculous cholecystitis, percutaneous cholecystostomy

35. EXPLANATION

C. Cholangiocarcinoma (CC). CC is the most likely diagnosis given the indolent presentation, nontender abdominal exams, elevation in ALP, and conjugated bilirubin, as well as the ultrasound finding of a gallbladder with heterogenic sludge. CC is a malignant tumor arising from cholangiocytes in the biliary tree. It tends to have a poor prognosis and high morbidity. It is the second most common primary hepatic tumor, with intrahepatic CCs accounting for 10% to 20% of primary liver tumors. Signs and symptoms of CC include jaundice, pruritus, white-colored stools, fatigue, abdominal pain, and unintended weight loss.

Ultrasound is not reliable in detecting small intrahepatic masses, nor extrahepatic and peritoneal metastases, but it can detect involvement of the gallbladder as well as the biliary tree. This is important because the most common variant of CC is peri-hilar, which accounts for about two-thirds of cases (Figure 7.50). Therefore, patients presenting with painless jaundice, labs consistent with cholestasis, and evidence of gallbladder or biliary mass or sludge should raise suspicion for malignancy, particularly CC.

Learning Points: A diagnosis of cholangiocarcinoma should be considered if there are signs of biliary obstruction (e.g., jaundice, abnormal liver tests in a cholestatic pattern, bile duct dilation on imaging studies) without an alternative explanation (e.g., choledocholithiasis or a pancreatic head lesion).

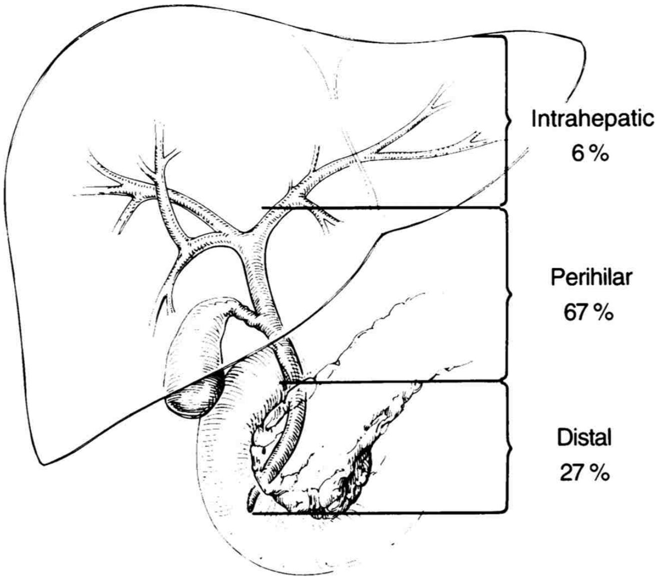

Figure 7.50 **Distribution of cholangiocarcinoma.** The vast majority of cholangiocarcinomas are peri-hilar, involving the gallbladder and/or biliary tree. One-quarter of cases are extra-hepatic, involving the common bile duct and pancreas. While rare, intrahepatic cholangiocarcinoma may be difficult to diagnose as patients typically do not present with jaundice nor elevation in conjugated bilirubin. Ultrasound can also be used to assess for involvement of the portal vein and hepatic veins in cholangiocarcinoma. Adapted from Figure 1 of Nakeeb A, Pitt HA, Sohn TA, et al. Cholangiocarcinoma: a spectrum of intrahepatic, perihilar, and distal tumors. *Ann Surg.* 1996;224(4):463–475.

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Keywords/Tags: Cholangiocarcinoma, bile duct cancer, jaundice

36. EXPLANATION

B. Rotate the transducer to obtain a transverse axis. By doing this, edge artifact is confirmed. If a gallstone is present, the shadowing is typically central, as the stone is likely gravity dependent and would rest centrally at the most posterior point of the gallbladder. In edge artifact, a sound wave will refract off a curved surface rather than echoing back to the transducer. As a result, there is attenuation in the same pathway of the sound wave, but distal to the curved surface (Figure 7.51). Once identified as an artifact, there is no need to confirm with a consultative ultrasound, nor any need to contact surgery. The patient may be discharged after other important diagnoses are considered and she improves, but this is too premature.

> **Learning Points:** Edge artifact may be mistaken for a gallstone in the neck. It can be distinguished by obtaining a transverse view and determining the location of shadowing.

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Kremkau FW, Taylor KJ. Artifacts in ultrasound imaging. *J Ultrasound Med*. 1986;5(4):227–237.

Keywords/Tags: Edge artifact, stone in neck, physics

37. EXPLANATION

D. Adenomyomatosis. This is characterized by hyperplasia of the gallbladder wall with formation of diverticula called Rokitansky–Aschoff sinuses that may serve as pockets for bile deposition and calcifications (arrow). There are three types—segmental, fundal, and diffuse—with segmental being the most common (Figure 7.52). Adenomyomatosis is typically asymptomatic, benign, and idiopathic. It is usually seen in the fifth or sixth decades of life. On ultrasound, there is thickening of wall sometimes with sinuses seen, as well as calcifications, ring-down artifact, and twinkling sign on color Doppler. If there is diagnostic uncertainty, a consultative ultrasound or MRCP and follow-up are recommended.

> **Learning Points:** Adenomyomatosis of the gallbladder wall is a common, benign hyperplasia of the wall with formation of Rokitansky–Aschoff sinuses. The wall can appear irregular with calcifications, ring-down artifact, as well as twinkling artifact on color Doppler.

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Hammad AY, Miura JT, Turaga KK, et al. A literature review of radiological findings to guide the diagnosis of gallbladder adenomyomatosis. *HPB*. 2016;18:129–135.

Keywords/Tags: Adenomyomatosis, Rokitansky–Aschoff sinus, twinkling sign, ring-down artifact

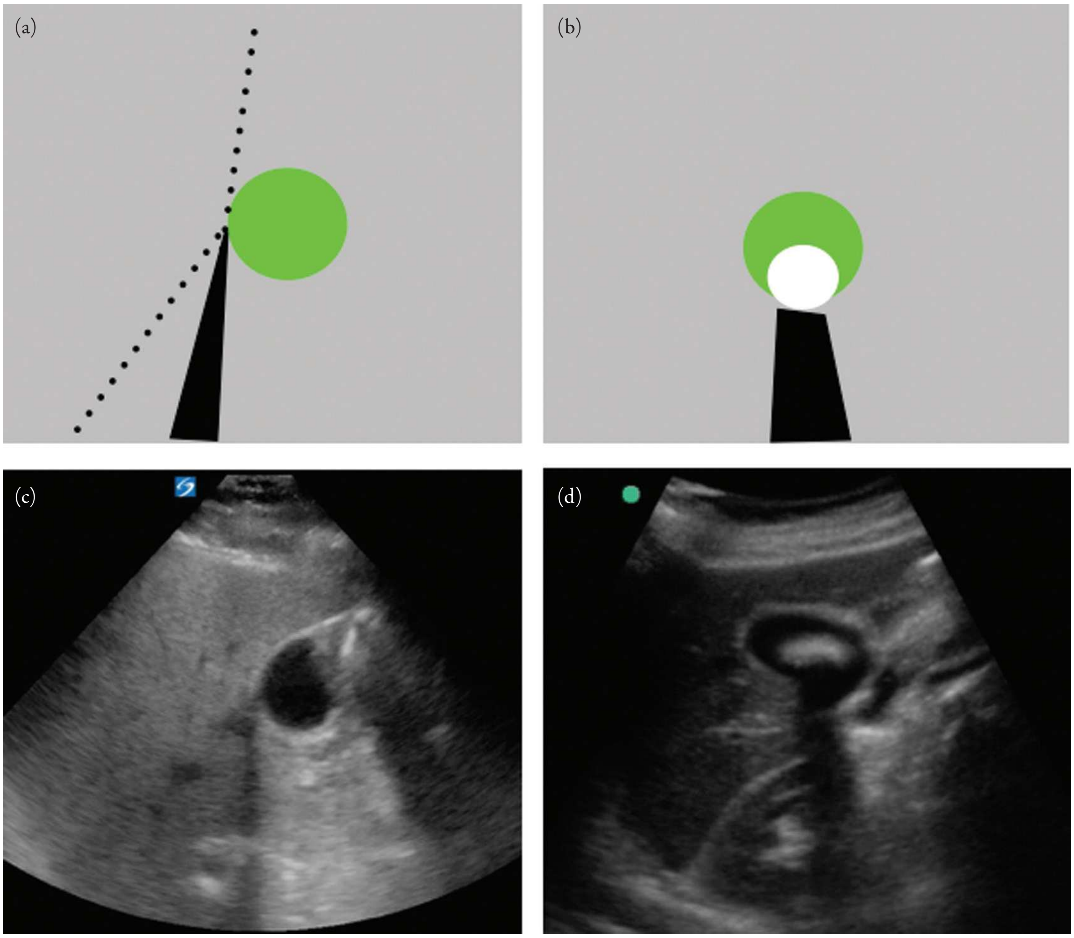

Figure 7.51 **Edge artifact versus gallstone.** In a long axis plane of the gallbladder, edge artifact typically occurs at the neck. To distinguish from a true gallstone, rotate the transducer to obtain a short axis view of the gallbladder neck. Edge artifact will then manifest as shadowing or attenuation laterally (Panels (a) and (c)), since the refractive sound wave (dashed line) travels laterally after striking the curved edge of the gallbladder. If a gallstone is present, the shadowing is usually central, or just deep to where the stone resides (Panels (b) and (d)).

38. EXPLANATION

C. Liver abscess. The irregular cystic appearance within the liver parenchyma and his septic appearance suggest a liver abscess. The most likely diagnosis is an amebic abscess (e.g., *Entamoeba histolytica*). However, other causative agents could be *Klebsiella, E. coli, Pseudomonas, Streptococcus,* anaerobic species, as well as *Echinococcus* (typically multicystic) and tuberculosis. Of note, unless the entire liver is imaged on ultrasound, a small hepatic abscess may be missed. Therefore, a CT scan with IV contrast is warranted if clinical suspicion is high and the ultrasound is normal. Upon diagnosis, treatment is aimed at fluid resuscitation, empiric antibiotics, and consultation with interventional radiology for emergent ultrasound or CT-guided aspiration of the abscess.

Learning Points: Liver abscesses are usually irregular and cystic in appearance. While the etiology may be suggested by the presentation, IR drainage is both curative and diagnostic.

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Keywords/Tags: Liver abscess, amebic abscess, echinococcus

39. EXPLANATION

B. A. portal vein, B. celiac trunk, C. aorta, D. IVC. While assessment of the pancreas is not considered a core

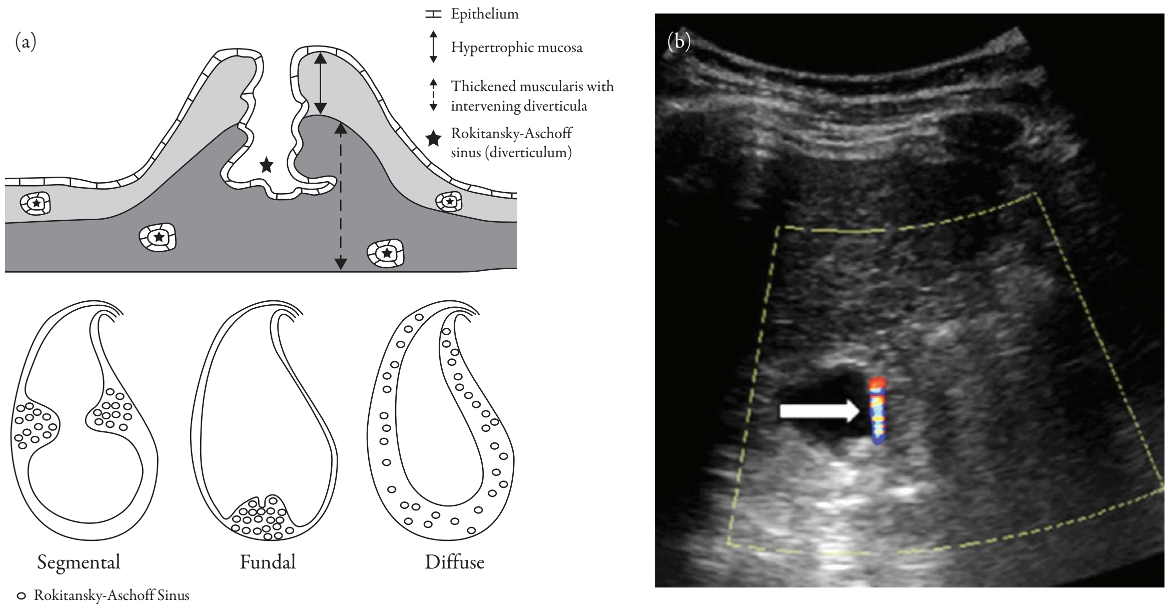

Figure 7.52 (a) **Adenomyomatosis formation and types.** While the pathogenesis is not completely understood, there is hyperplasia of the mucosa and muscle layers of the wall. These allow for the formation of diverticula called Rokitansky–Aschoff sinuses that may contain bile, calcifications, or even gallstones (Panel a). The most common type is the segmental type, followed by diffuse and fundal types (Panel b). Adapted from Figures 1 and 3 of Golse N, Lewin M, Rode A, Sebagh M, Mabrut JY. Gallbladder adenomyomatosis: diagnosis and management. *J Visceral Surg.* 2017;154:345–353. (b) **Adenomyomatosis on ultrasound.** In addition to irregular wall thickening with visualization of the sinuses and calcifications, there is often ring-down artifact as well as the "twinkling sign" on color Doppler. Adapted from Figure 2 of Hammad AY, Miura JT, Turaga KK, et al. A literature review of radiological findings to guide the diagnosis of gallbladder adenomyomatosis. *HPB.* 2016;18:129–135.

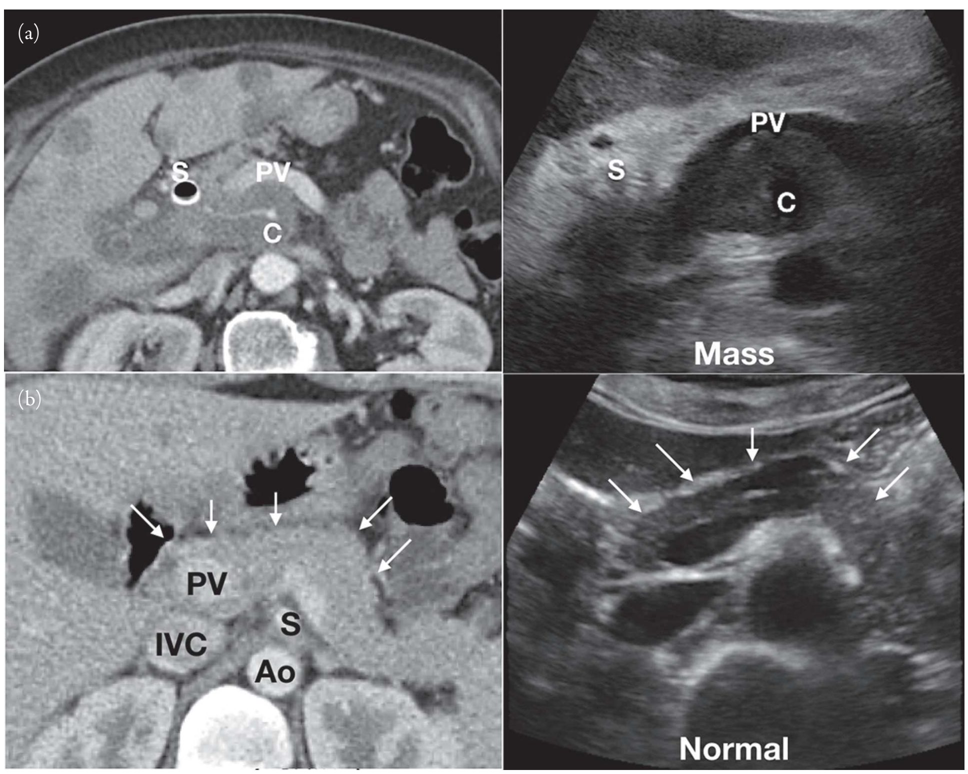

Figure 7.53 (a) **Pancreatic head mass on computed tomography (CT) and ultrasound (US).** The top panel shows an axial CT plane while the bottom panel shows the representative US plane of this patient with pancreatic cancer. The pancreatic mass encases the portal vein (PV) as well as the celiac trunk (C). There is a biliary stent that has been placed (S) for management of the patient's obstructive jaundice. Note also the many liver metastases on CT. (b) **Identification of the pancreas.** The left panel shows a computed tomography (CT) axial cut of normal hepatobiliary anatomy, while the right shows a representative ultrasound image. The pancreas (arrows) lies just anterior to where the portal vein forms from the mesenteric veins and the splenic vein (PV). The pancreatic head lies anterior to the inferior vena cava, while the tail surrounds the aorta (Ao). The superior mesenteric artery (S) lies just posterior to the pancreatic body. Knowing the relative vascular anatomy allows the sonographer to identify the pancreas, which can be difficult as it is usually iso-echoic with the liver.

application for the clinician sonographer, it may lead to the diagnosis in patients that present with painless jaundice. In this case, there is a large pancreatic head mass that is leading to obstructive jaundice. Further workup should include a CT with IV contrast as well as consultation with surgery and gastroenterology. Her prognosis is poor given the involvement of the portal vein and celiac trunk.

The pancreas is often isoechoic with the liver, so identification can be difficult for the sonographer (Figure 7.53). Color Doppler can be used to identify adjacent vascular structures that can lead to identification of the pancreas. The pancreas lies just anterior to where the splenic vein meets with the mesenteric veins to form the portal vein. The pancreatic head lies also anterior to the IVC, whereas the body and tail typically surrounds the aorta. In addition, the superior mesenteric artery typically courses just posterior to the pancreatic body. In addition, portal vein thrombosis, a known complication of pancreatic cancer, can be assessed with color Doppler as well.

Learning Points: Pancreatic head masses should be considered when patients present with painless jaundice. The pancreas lies just anterior to the confluence of the splenic and mesenteric veins as they form the portal vein.

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Keywords/Tags: Pancreas, painless jaundice, pancreatic cancer, portal vein

8.

RENAL ULTRASOUND

Amir Aminlari, Michael A. Macias, Virag J. Shah, and Anthony J. Medak

QUESTIONS

1. A 44-year-old man presents to the emergency department (ED) with acute flank pain. You wish to assess for hydronephrosis as well as any evidence of renal or ureteral stones. Which probe, exam setting, and patient position do you use?

A. Linear probe, abdominal setting, Trendelenberg position
B. Vascular probe, pelvis setting, supine position
C. Phased array probe, abdominal setting, supine position
D. Phased array probe, vascular setting, reverse Trendelenberg position

2. Which of the following choices correctly describes the sonographic renal anatomy in Figure 8.1?

A. 1 = Perinephric fat, 2 = renal column, 3 = renal hilum
B. 1 = Renal cortex, 2 = renal cyst, 3 = renal pyramid
C. 1 = Renal cortex, 2 = renal pyramid, 3 = renal sinus
D. 1 = Renal medulla, 2 = renal cyst, 3 = minor calyx

3. A 35-year-old man is transported to the ED by ambulance after a motor vehicle crash. He has normal vital signs but has some mild abdominal tenderness on exam. Using the image in Figure 8.2, identify the structure marked with the arrow:

A. Prostate gland
B. Left ureter
C. Free fluid in pelvis
D. Seminal vesicles

4. A 65-year-old woman presents to the ED with abdominal/flank pain and reports some discoloration of her urine. You perform a bedside ultrasound exam, shown in Figure 8.3. Which of the following statements best describes the findings of your exam?

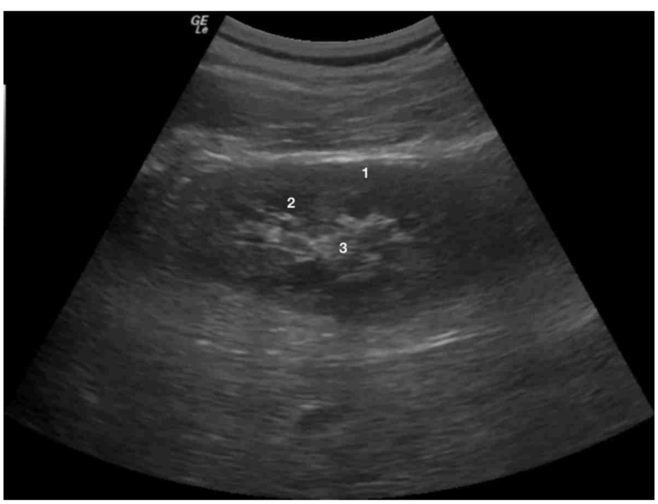

Figure 8.1 Image from Radiopaedia, Case courtesy of Dr Matthew Lukies, Radiopaedia.org, rID: 50538.

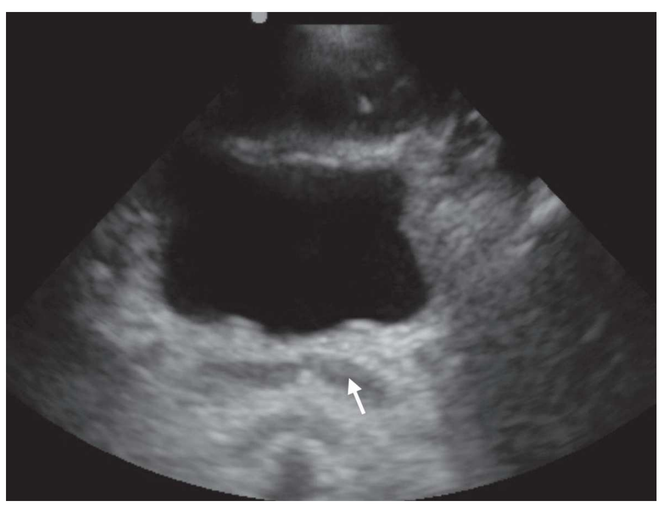

Figure 8.2

Figure 8.3

A. Moderate hydronephrosis
B. Renal cell carcinoma
C. Calyceal rupture
D. Nonobstructing nephrolithiasis

5. A 54-year-old female with a history of uterine cancer presents with bilateral flank pain. Her symptoms started 1 week ago and have progressively worsened. She states that her urine output has also slowed considerably over the last 2 days. She complains of nausea but no vomiting. She denies fevers and chills and has normal vital signs. She has a mildly distended abdomen, as well as moderate costovertebral angle (CVA) tenderness bilaterally. A chemistry panel is notable for a blood urea nitrogen and creatinine of 32 and 2.6, respectively. You perform a bedside renal ultrasound (see Figure 8.4). The contralateral kidney appears very similar to the image provided. The postvoid residual (PVR) volume is 35 ml. Aside from obtaining further imaging such as a computed tomography (CT) scan, what is the best next step in management?

A. Insert Foley catheter
B. Administer 40 mg furosemide intravenously
C. Consult Interventional Radiology for bilateral percutaneous nephrostomy tubes
D. Consult Gynecology/Oncology for endometrial biopsy

6. A 39-year-old male with history of kidney stones presents with right flank pain and vomiting. On exam he has significant right flank tenderness. His heart rate is 110 and the rest of his vital signs are normal. A point-of-care ultrasound (POCUS) is performed (see Figure 8.5). What is the diagnosis?

A. Mild hydronephrosis
B. Mild to moderate hydronephrosis
C. Moderate hydronephrosis
D. Severe hydronephrosis

7. A 27-year-old male with a past medical history of kidney stones presents with a chief complaint of sudden-onset left flank pain. Symptoms started 2 hours prior to arrival. The pain radiates to the left lower quadrant and left groin. The patient is writhing around on the gurney and vomiting during your evaluation. He is afebrile but tachycardic to 119 and hypertensive to 167/87. He has mild tenderness to percussion at the left CVA. Bedside urinalysis reveals large blood but is negative for leukocytes or nitrites. You perform a bedside ultrasound and obtain the image shown in Figure 8.6. What is the best next step in management for this patient?

A. CT abdomen and pelvis to assess for degree of hydronephrosis
B. Symptom control with analgesics and antiemetics, followed by discharge with urine strainer, outpatient follow-up, and strict return precautions

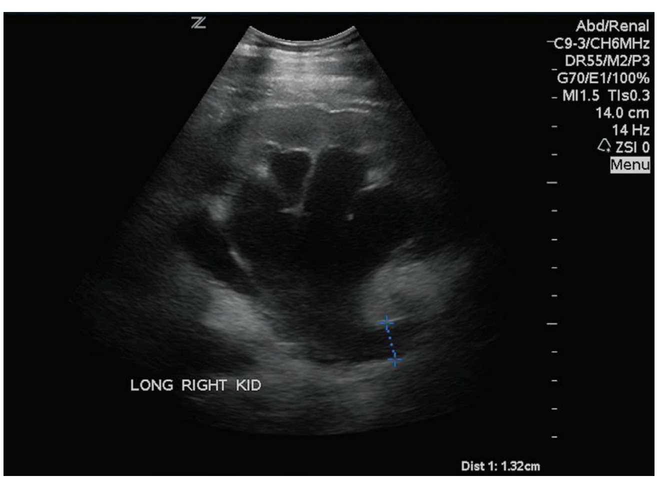

Figure 8.4

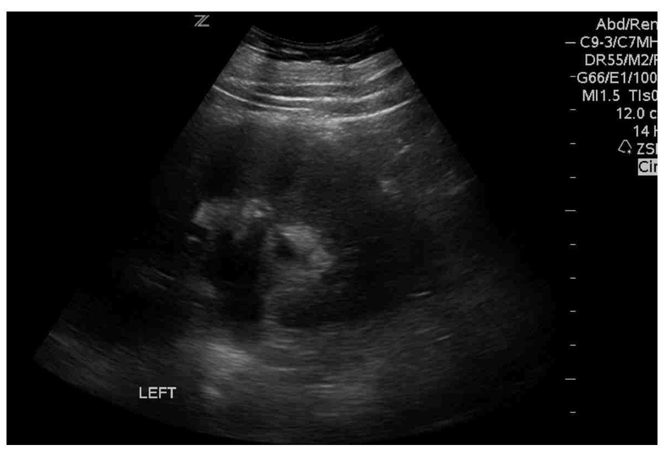

Figure 8.5

C. Complete blood count, c-reative protein, urine culture, blood culture, symptom control, and admission for antibiotics and continued management
D. Intraveneous (IV) opioid for pain, IV labetalol for blood pressure and tachycardia control, followed by Urology consultation

8. The same 27-year-old patient from Question 7 returns 2 days later complaining of worsening pain, chills, persistent nausea, and vomiting. His temperature is 102.1°F, heart rate is 137, and blood pressure is 93/47. On examination he appears dehydrated and has exquisite tenderness to percussion over the right CVA. His urinalysis is notable for large white blood cells (WBC) and bacteria and large blood. His WBC is 21K and his lactate is 4.3. He is started on IV antibiotics and IV fluids. His bedside ultrasound is notable for that shown in Figure 8.7. What is the best next step in management?

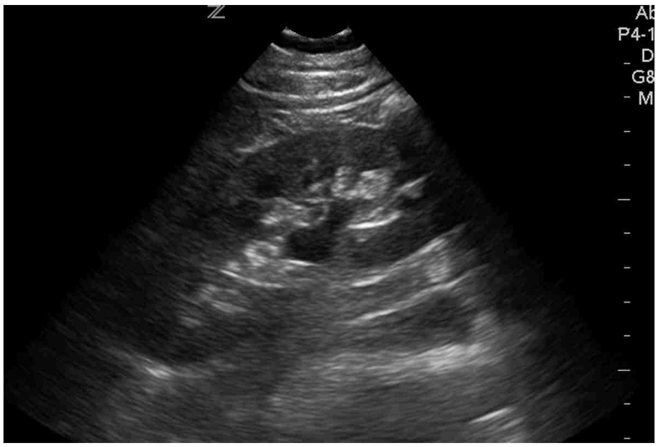

Figure 8.6

A. Consult Urology and Interventional Radiology for percutaneous nephrostomy tube
B. Order a CT of the abdomen and pelvis to identify the source of the fever
C. Symptom control and admission for antibiotics and continued management
D. Treat the patient symptomatically with oral acetaminophen, IV ketorolac, antiemetics, and IV fluids. Discharge with oral antibiotics

9. A 44-year-old female presents with a chief complaint of right flank pain. Her symptoms started approximately 3 weeks ago and have gradually worsened. She denies abdominal pain, fever, dysuria, or hematuria. On exam you find a well-appearing woman with normal vital signs. She has mild right CVA tenderness. Her exam is otherwise normal. A bedside renal ultrasound shows the image in Figure 8.8. Which statement best describes the findings in this image?

Figure 8.7

A. No hydronephrosis
B. Mild hydronephrosis
C. Moderate hydronephrosis
D. Severe hydronephrosis

10. A 77-year-old male with a history of peripheral vascular disease, hypertension, coronary artery disease, and a 50-pack/year history of smoking presents with left flank pain for several weeks. The flank pain suddenly worsened prior to arrival. His pain radiates to the left lower quadrant. He denies fevers, chills, dysuria, or hematuria. On exam the patient is in obvious pain. His vitals are temperature 98.4°, heart rate 112, respiratory rate 22, blood pressure 90/55, and SpO_2 97%. He is diaphoretic. He has left CVA tenderness as well as left lower quadrant tenderness. A bedside ultrasound of the kidneys shows

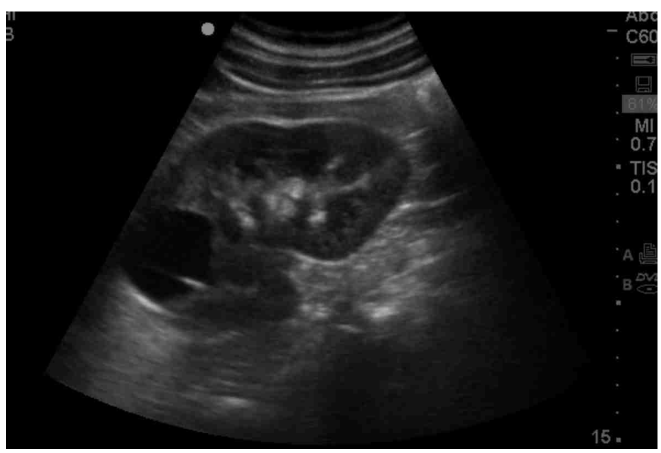

Figure 8.8

no evidence of hydronephrosis. What is the next best step in management?

A. Obtain CT abdomen/pelvis with IV contrast
B. Emergent Urology consult
C. Perform a bedside ultrasound of the aorta as well as a FAST exam
D. Order electrocardiogram (ECG), chest X-ray (CXR), and cardiac markers

11. An 81-year-old Chinese man is brought to the ED by his granddaughter. She states that for the past few days his urine has been pink. Today he noticed gross red blood. He denies any pain or discomfort. He denies fever or chills. He denies frequency or dysuria. On exam you find a well-appearing man in no distress. His vital signs are normal. You perform a bedside renal ultrasound (see Figure 8.9). What is the best next step in management?

A. Order urine culture, antibiotics, and discharge with primary care follow-up
B. Order Foley catheter, serial hemoglobin, urinalysis, and urine culture
C. Administer IV ketorolac and an antiemetic
D. Obtain a CT of the abdomen and pelvis and request Urology consultation or outpatient referral

12. A 68-year-old male with no prior medical problems presents for evaluation after being unable to urinate for 24 hours. The patient has normal vital signs and appears nontoxic. He reports pelvic pressure with suprapubic fullness on exam. He admits to experiencing nocturia, a slow urinary stream, and urgency, which have progressed over the past several years but for which he has not sought prior care. You proceed to evaluate the patient with a transabdominal pelvic ultrasound (see Figure 8.10 and Video 8.1), which most likely represents which pathology?

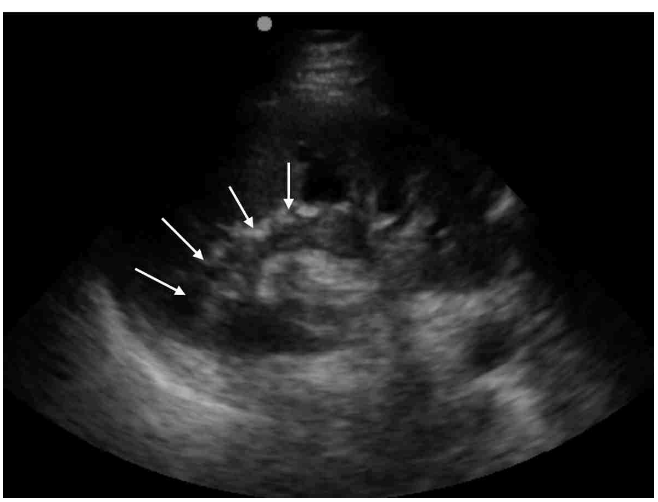

Figure 8.9

Figure 8.10 **Distended urinary bladder containing urine.** An enlarged prostate with some degree of intravesical prostatic protrusion is noted.

A. Acute urinary retention (AUR) due to urethral stricture
B. AUR due to prostatic enlargement
C. Chronic cystitis due to recurrent urinary tract infections
D. AUR due to bladder carcinoma

13. A 37-year-old female presents to the ED with sudden-onset pelvic pain for 1 day. She denies urinary complaints or vaginal bleeding and has normal vital signs. She reports similar symptoms in the past due to a ruptured ovarian cyst. Her pregnancy test is negative. Prior to transvaginal ultrasound, you wish to perform a transabdominal pelvic ultrasound to evaluate the urinary bladder and assess for free fluid in the pelvis. Which of the following describes your approach?

A. Placing the probe in the infraumbilical region, tilt the probe caudally to direct the ultrasound beam into the pelvis. Ensure to scan thoroughly in the sagittal plane to assess for free fluid.
B. Placing the probe just cephalad to the pubic symphysis, tilt the probe caudally to direct the ultrasound beam into the pelvis. Ensure to scan in thoroughly in the sagittal plane to assess for free fluid.
C. Placing the probe just cephalad to the pubic symphysis, visualize the urinary bladder. Ensure to scan thoroughly in the sagittal and transverse planes to assess for free fluid.
D. A transvaginal pelvic exam must be performed. Transabdominal pelvic ultrasound cannot be used for such an assessment.

14. A 38-year-old female with history of multiple sclerosis presents with a worsening sensation of incomplete emptying after attempts to urinate. She reports a gradually reduced urgency to void over several years, accompanied by hesitancy in initiating flow of urine. When

performing a bedside ultrasound, you calculate the volume of urine left in the bladder at the completion of micturition as noted in the Figure 8.11. How would you interpret this result?**

A. Abnormal PVR
B. Normal PVR
C. Clinical correlation is required given that the patient is a female
D. Bedside ultrasound is not relevant in determining a PVR value

15. In the patient described in Question 14, you decide to use the following formula to calculate the PVR volume: 0.7 × Height (H) × Width (W) × Depth (D). Describe how you go about obtaining these measurements for the formula.

A. Obtain bladder width measurement (right to left) in transverse plane. Then rotate the probe 90° and measure the bladder's craniocaudal height in sagittal plane.
B. Obtain the bladder width measurement in transverse plane. Then continue to visualize the bladder in transverse plane and measure the anterior-posterior depth (from near field to far field on the screen).
C. In transverse plane, measure the bladder width (right to left) and anterior-posterior depth (near field to far field on screen). Then rotate the probe 90° and measure the bladder's craniocaudal height in sagittal plane.
D. Obtain bladder width, height, and depth in the sagittal plane.

16. A 31-year-old male with a history of high cholesterol presents with a sudden onset of right flank pain radiating to the groin, accompanied by 1 episode of vomiting. He denies fever or urinary retention. A genitourinary exam is performed and is normal. The abdomen is non-tender. A point-of-care urinalysis reveals trace blood and is negative for leukocyte esterase. What is the next appropriate diagnostic step in the care of this patient?

A. Ultrasound of the kidneys and urinary bladder
B. Urinary bladder catheterization
C. CT scan of the abdomen and pelvis
D. Ultrasound of the scrotum

17. A 32-year-old male presents with acute right flank pain. He reports no urinary retention. His vital signs are normal and he has moderate right flank tenderness on exam. A POCUS of the kidneys is performed and there is no evidence of hydronephrosis on either side. Ultrasound of the bladder reveals the images in Figure 8.12 and Video 8.2. What is significance of this finding?

A. Urethral obstruction with increased bladder volume
B. Prostatic enlargement with increased bladder volume
C. Echogenic bladder consistent with cystitis
D. Right ureteral obstruction

18. A fully distended urinary bladder (full of urine) is ideal for:

A. Transvaginal ultrasound to evaluate the uterus and pelvic contents.
B. Accurate calculation of bladder volume.
C. Limiting edge artifact.
D. Transabdominal ultrasound to evaluate the uterus and pelvic contents.

19. An otherwise healthy 31-year-old female patient presents to the ED with left flank pain. Her urinalysis is notable only for moderate blood. Urine human chorionic

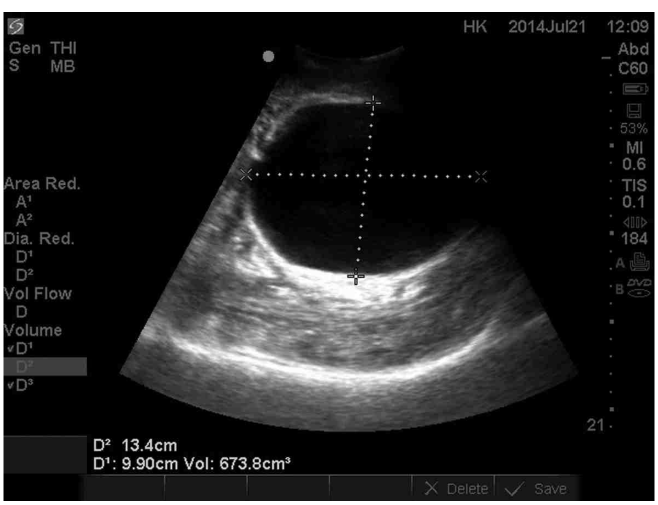

Figure 8.11

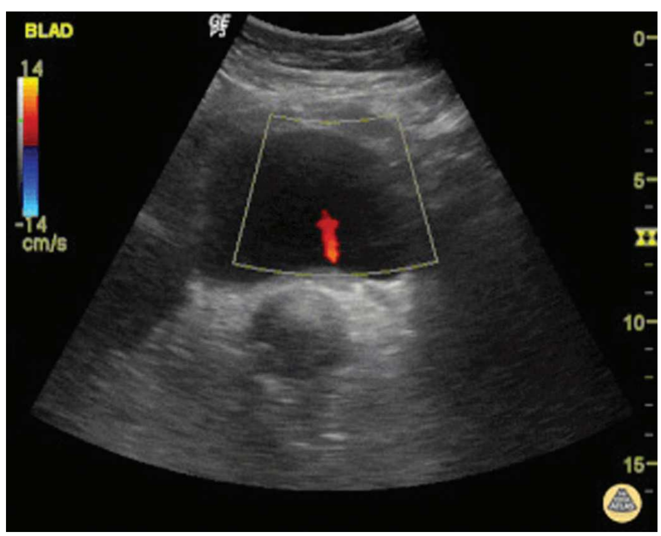

Figure 8.12

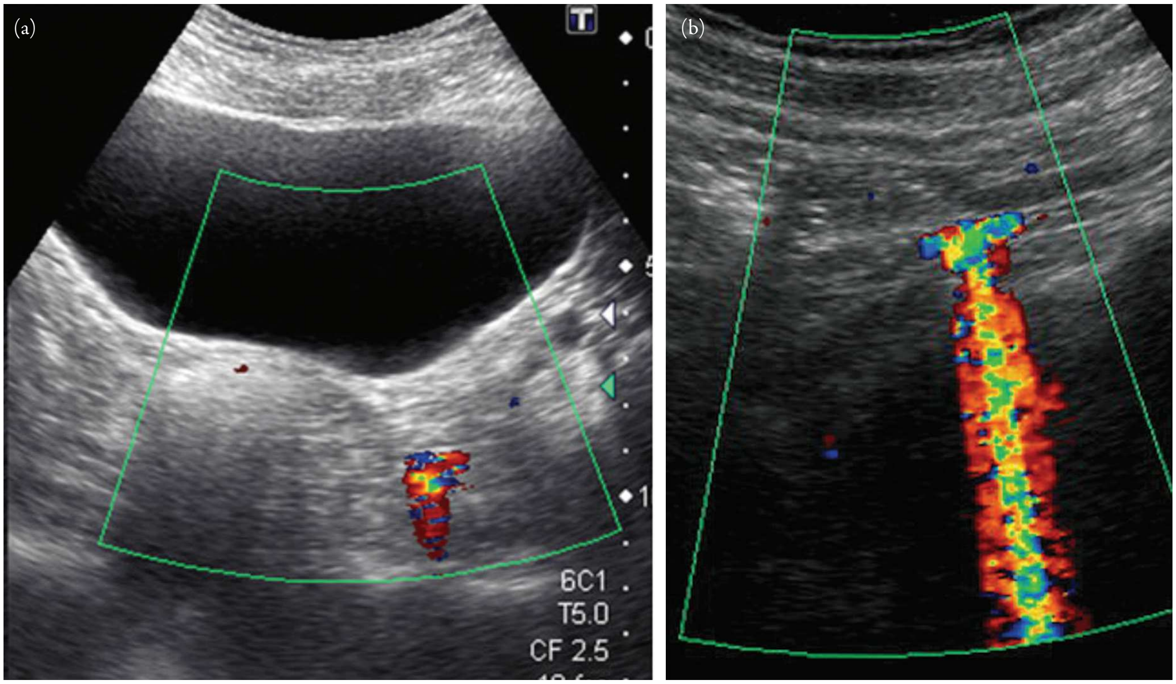

Figure 8.13

gonadotropin (hCG) is negative. She is comfortable after pain management. A bedside ultrasound is performed, as shown in Figure 8.13. What is the next best step in management?

A. Obtain a CT scan to further evaluate the cause of her pain.
B. Obtain transvaginal ultrasound to further evaluate the cause of her pain.
C. Consult Urology.
D. Discharge home with a urine strainer and Urology follow-up.

20. An 84-year-old male with recent Foley catheter placement secondary to BPH presents with decreased urine output for the past day. His caregiver notes he was pulling on the catheter and thinks it may have become dislodged. A bedside ultrasound is performed (see Figure 8.14). What is the next best step in management?

A. Advance the catheter several centimeters.
B. Remove current catheter and replace with a new one.
C. Irrigate the catheter.
D. Add volume to Foley balloon to reposition tip of catheter.

21. A 35-year-old female with a history of nephrolithiasis presents with right sided flank pain that started acutely earlier today. She notes she has previously had no surgical intervention for her ureteral stones in the past. A bedside ultrasound is performed (see Figure 8.6). Her urinalysis shows no signs of infection, and her pain is controlled with IV ketorolac. The patient is informed that recurrent nephrolithiasis is suspected to be the etiology of her pain. What other counseling should be provided to the patient?

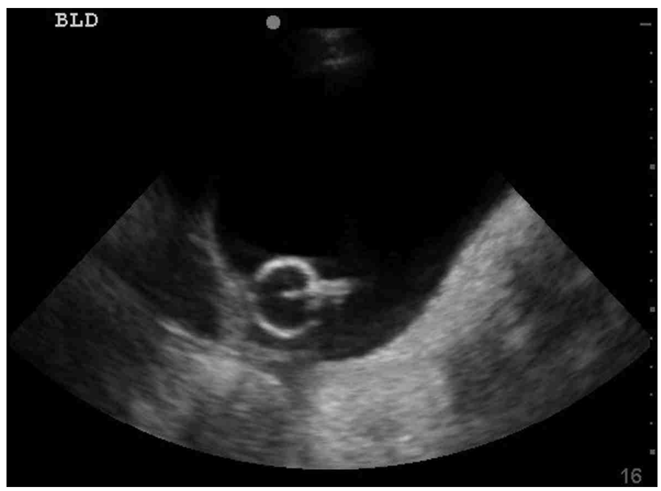

Figure 8.14

A. Recommend CT scan to evaluate for stone size and location
B. Reassure that current kidney stone is likely to pass on its own
C. Recommend urgent follow-up with Urology as current kidney stone will likely need surgery
D. Recommend urology consultation in the ED

22. A 20-year-old male presents to the ED with left-sided flank pain. He notes a history of recurrent pain to both flanks but has never seen a physician for this issue. He states that he has some relatives with a "kidney issue." He presented today because he noticed a small amount of blood in his urine. The patient appears in no acute distress with a benign physical exam. His urinalysis shows a large amount of blood but no signs of infection. He has normal renal function. A bedside ultrasound is performed (see Figure 8.15). How would you counsel the patient on further management?

A. Recommend pain control and referral to primary care physician and Nephrologist
B. Recommend CT scan to evaluate for ureteral stones
C. Recommend urgent urology consultation in the ED
D. Recommend CT scan to evaluate for alternative etiology of his symptoms

23. A 35-year-old female presents to the ED after a low-speed motor vehicle collision for medical evaluation. She was the restrained driver and notes that she feels fine other than some mild body aches but wanted to get checked out. She has normal vital signs and a benign physical exam and appears comfortable. A FAST exam is performed and is without any evidence of free fluid; however, the finding in Figure 8.16 is noted. What is the next best step in management?

A. CT scan to evaluate for traumatic kidney injury
B. Urology consultation in the ED
C. Referral to primary care physician for further medical workup
D. Obtain urinalysis to evaluate for infection

24. A 45-year-old female with no past medical history presents to the ED with right-sided abdominal pain. A bedside ultrasound is performed, and during the examination the finding in Figure 8.17 is noted. How would you counsel the patient?

A. Recommend CT scan in ED for further evaluation
B. Provide reassurance and refer to Urology
C. Express concern regarding possible malignancy and refer to Oncology
D. Provide reassurance and refer to primary care physician for follow-up

Figure 8.15

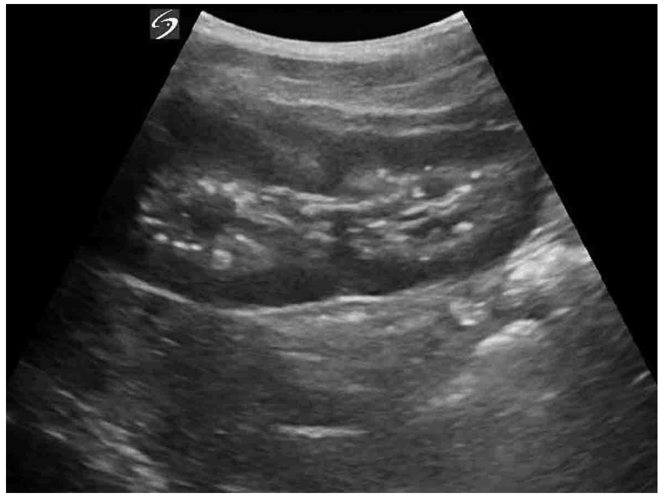

Figure 8.16

25. A 50-year-old female with a history of diabetes presents with fever and severe right-sided flank pain. She notes she was diagnosed with a urinary tract infection 1 week ago for which she is taking Macrobid. The patient is febrile to 103.1° and appears toxic and uncomfortable. Her urinalysis is consistent with an acute infection. Broad-spectrum antibiotics are initiated. A bedside ultrasound is performed (see Figure 8.18 and Video 8.3). What is the next best step in management?

A. Emergent Urology consultation
B. CT scan to evaluate for obstructing ureteral stone

Figure 8.17

C. Admission to hospital for ongoing antibiotic therapy
D. Admission to medical intensive care unit for ongoing antibiotic therapy

Figure 8.18

ANSWERS

1. EXPLANATION

C. Phased array probe, abdominal setting, supine position. An appropriate probe would be a low-frequency phased-array transducer. The small probe footprint allows for easy manipulation between the ribs. Another acceptable option is to use a curved array transducer. The ultrasound system should be set to an "abdominal" or "renal" setting.

Place the patient in a supine position with the ipsilateral arm raised above the head (Figure 8.19). To image the right kidney, place the probe in the mid-axillary line, at the lower costal margin. To image the left kidney, the technique is similar; however, one must place the probe more posteriorly on the flank (in the posterior axillary line) for best imaging results.

Figure 8.19 **Patient positioning for renal ultrasound exam.**

Because of the oblique lie of the kidneys, it is often necessary to rotate the probe such that the ultrasound beam is parallel to the plane of the ribs. Have the patient take a deep breath while performing the exam to bring the kidneys closer into view and thereby decrease the extent of rib shadow artifact.

Learning Points: To enhance the ability to visualize the kidney, have the patient take a deep breath. This will decrease acoustic shadowing from the ribs.

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Keywords/Tags: Renal, knobology, acquisition, patient position

2. EXPLANATION

C. 1 = Renal cortex, 2 = renal pyramid, 3 = renal sinus. Each kidney is well demarcated by a brightly echogenic fibrous capsule surrounded by a variable amount of perinephric fat. In comparison to the liver, the normal renal parenchyma is less echogenic. Individual pyramids may (or may not) be visible as hypoechoic triangular shaped structures within the renal medulla.

The central area of the kidney is the renal sinus, which is deep to the medulla. The renal sinus appears highly echogenic due to its high fat content. The renal sinus contains the minor and major calyces that empty into the renal pelvis. Note that the normal ureter is generally not seen on ultrasound, unless it is dilated due to obstruction.

Learning Points: In the normal kidney, the renal sinus is easily recognizable due to it's highly echogenic appearance. As hydronepohrosis progresses, this echogenic appearance becomes increasingly anechoic due to the accumulation of urine.

REFERENCE

Seif D, Swadron SP. Renal. In: Ma OJ, Mateer JR, Reardon RF, Joing SA, eds. *Ma & Mateer's Emergency Ultrasound*. 3rd ed. New York, NY: McGraw-Hill; 2014:319–352.

Keywords/Tags: Renal, anatomy, renal cortex, renal pyramids, renal pelvis, renal sinus

3. EXPLANATION

D. Seminal vesicles. The shape and appearance of the bladder on ultrasound depends on its degree of filling. When relatively full, the bladder walls appear as an echogenic line surrounding an anechoic cavity. The prostate gland may be recognized as an oval hypoechoic structure posterior to the bladder.

The seminal vesicles are fluid-filled structures located between the prostate and bladder (Figure 8.20). In general,

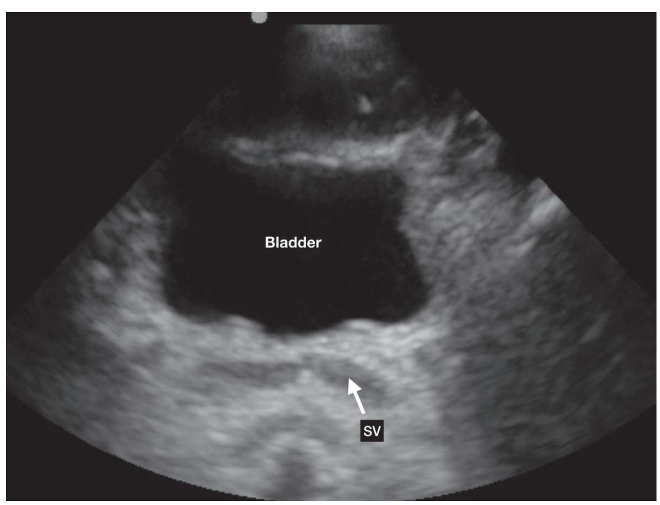

Figure 8.20

they will appear as hypoechoic to anechoic on the ultrasound image. This relationship is important to understand. If the seminal vesicles are not recognized, they may be mistaken for free fluid in the pelvis and result in a false-positive Focused Assessment with Sonography in Trauma (FAST) exam (Fernandez 1998).

Learning Points: The seminal vesicles are hypoechoic and located posterior to the bladder. If not recognized, they may be mistaken for pathologic free fluid when performing the FAST exam.

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Fernandez L, McKenney MG, McKenney KL, et al. Ultrasound in blunt abdominal trauma. *J Trauma*. 1998;45(4):841–848.

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Keywords/Tags: Bladder anatomy, seminal vesicles, prostate, male pelvis

Figure 8.21 Angiomyolipoma.

Learning Points: Not all hyperechoic lesions within the kidney are indicative of nephrolithiasis. Renal stones *must* demonstrate acoustic shadowing. If no shadowing is observed, one must consider other pathology such as RCC or AML.

4. EXPLANATION

D. Nonobstructing nephrolithiasis. Renal stones may lodge anywhere within the genitourinary tract and can be visualized within the kidney itself, the ureter, and the bladder. As one would expect, the stones appear as echogenic structures with posterior acoustic shadowing. Stones are rarely visualized in the mid-ureter (often obscured by bowel gas) but may be identified at the ureteropelvic or ureterovesicular junctions, which are 2 common locations of obstruction. The figure shows the renal stone in the pelvis of the kidney with shadowing from the stone (Figure 8.3). Stones may also be seen in the bladder. Asymptomatic stones within the renal parenchyma are not uncommon. Boyce et al. demonstrated an 8% prevalence of urolithiasis in a cohort of over 5,000 asymptomatic patients.

It is important to realize that not all focal hyperechoic lesions within the kidney are consistent with urolithiasis. A stone *must* have posterior acoustic shadowing. If a hyperechoic lesion with no acoustic shadow is seen within the kidney, one must consider a renal mass such as renal cell carcinoma (RCC) or angiomyolipoma (AML) (Forman 1993). RCC lesions are extremely variable in their sonographic appearance and can be hyperechoic, isoechoic, or hypoechoic. AML lesions are usually well demarcated and brightly echogenic on ultrasound with no shadowing (Figure 8.21).

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Keywords/Tags: Renal, nephrolithiasis, angiomyolipoma, renal mass, acoustic shadow

5. EXPLANATION

C. Consult Interventional Radiology for bilateral percutaneous nephrostomy tubes. The ultrasound image shows hydronephrosis. The contralateral kidney has the same appearance. Given that the patient's condition is further complicated by acute renal insufficiency, she requires prompt decompression with either percutaneous nephrostomy tubes or perhaps ureteral stents for obstruction caused likely by uterine mass. Choice A, insertion of Foley catheter, will be

useful for monitoring urine output but would not alleviate the ureteral obstruction. Also, the PVR volume is only 35 ml, making postobstructive etiology unlikely. Choice B, administration of furosemide, is inappropriate in a patient with acute obstructive uropathy. Choice D, consultation of Gynecology Oncology for surgical evaluation in this patient with uterine cancer, is useful but not the next step in management.

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Sountoulides P, Pardalidis N, Sofikitis N. Endourologic management of malignant ureteral obstruction: indications, results, and quality-of-life issues. *J Endourol*. 2010;24(1):129–142.

Keywords/Tags: Hydronephrosis, urinary tract decompression, nephrostomy tube, ureteral stent

6. EXPLANATION

C. Moderate hydronephrosis. Grading of hydronephrosis is based on the amount of dilation that the urine creates on specific portions of the renal system from the distal obstruction (Figure 8.22). For mild hydronephrosis (grade 1), there is pelviectesis (dilation of the renal pelvis). In moderate hydronephrosis there is a full pelvis and major calyces are dilated (grade 2), and progression will lead to uniformly dilated minor calyces (grade 3) with no cortical involvement. In severe hydronephrosis (grade 4), there is parenchymal compromise with thinning of the renal cortex.

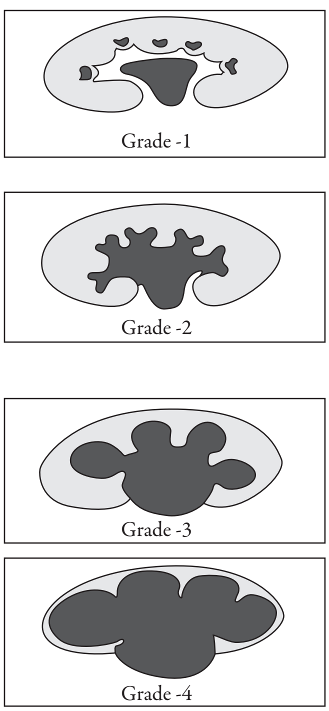

Figure 8.22 Grading of Hydronephrosis. Adapted from Figure 1, de Bessa J, Rodrigues CM, Chammas MC, et al. Diagnostic accuracy of Onen's Alternative Grading System combined with Doppler evaluation of ureteral jets as an alternative in the diagnosis of obstructive hydronephrosis in children. *Peer J.* 2018;6:e4791. doi:10.7717/peerj.4791.

Learning Points: Hydronephrosis from ureteral obstruction will first affect the renal pelvis (pelviectesis), then the calyces, and lastly the renal cortex.

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Keywords/Tags: Hydronephrosis, grading, renal obstruction

7. EXPLANATION

B. Symptom control with analgesics and antiemetics, followed by discharge with urine strainer, outpatient follow-up, and strict return precautions. The bedside ultrasound shows mild hydronephrosis with pelviectasis of the left kidney. Given these findings and the presenting symptoms, it is most likely that the patient has unilateral ureteral obstruction of the left side. Choice B is the most appropriate choice of management for this patient. If the patient's symptoms are controlled and they are able to tolerate oral intake then outpatient management is appropriate. Choice A is incorrect because the additional information gleaned from a CT scan of the abdomen and pelvis (such as stone size and exact ureteral location) does not justify the significant amount of radiation incurred and ultimately will not change patient management (Smith-Bindman 2014). Choice C is incorrect because the patient does not clinically have signs of an infected stone. Choice D is incorrect because labetaolol is not indicated for the treatment of symptomatic ureterolithiasis; the tachycardia and hypertension are secondary to pain and will improve with analgesia and IV fluids. Urology consultation is not routinely required in the ED for uncomplicated ureterolithiasis.

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Ulusan S, Koc Z, Tokmak N. Accuracy of sonography for detecting renal stone: comparison with CT. *J Clin Ultrasound*. 2007;35(5):256–261.

Keywords/Tags: Renal stone, ureterolithiasis, hydronephrosis

8. EXPLANATION

A. Consult Urology and Interventional Radiology for percutaneous nephrostomy tube. This patient is septic secondary to an infected renal stone. He requires IV fluids and IV antibiotics, and interventional radiology or urology should be consulted for definitive management for decompression with percutaneous nephrostomy tube and/or ureteral stenting. He requires admission to the hospital for severe sepsis with early signs of septic shock. Borofsky et al. found that mortality in patients with ureteral calculi and sepsis was significantly higher in patients who did not receive decompression, 19.2% versus 8.82%. Table 8.1 lists indications for urology consultation and admission in patients with nephrolithiasis. Choices B, C, and D are incorrect as definitive management to relieve the obstruction is absent. In addition, choice D is incorrect because discharge of this septic patient without decompression and proper stabilization is an inappropriate course of action.

Table 8.1. **INDICATIONS FOR UROLOGY CONSULTATION AND ADMISSION IN PATIENTS WITH NEPHROLITHIASIS**

Indications for Inpatient Emergent Urology Consultation and Admission
• **Obstructing stone with proximal infection**
• **Severe hydronephrosis**
• **Urosepsis**
• **Acute renal failure**
• **Anuria**
• **Intractable pain, nausea, or vomiting**
Indications for Urgent Urology Consultation (1–2 days)
• **Nonobstructing stone with associated urinary tract infection**
• **Borderline creatinine level who are tolerating oral fluids**
Indications for Semiurgent Outpatient Urology Referral (5–7 days)
• **Stone larger than 10 mm with no obstruction**
• **Fail to pass stone after trail of conservative management**
• **History of multiple/recurrent stones**
• **Continued mild pain that can be controlled with oral analgesia**

Adapted from Graham A, Luber S, Wolfson AB. Urolithiasis in the emergency department. *Emerg Med Clin North Am*. 2011;29(3):519-538.

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Keywords/Tags: Infected renal stone, hydronephrosis, sepsis, nephrostomy tube

9. EXPLANATION

A. No hydronephrosis. There is no hydronephrosis present. The image depicts a large fluid-filled mass on the superior pole of the left kidney, likely representing a large renal cyst. Renal cysts are a common finding with a prevalence of 10.7% for simple renal cysts (Chang 2007). Risk factors for renal cysts include older age, male gender, elevated serum creatinine, and smoking. Renal cysts are present in the renal cortex, as opposed to hydronephrosis, which is seen within the renal collecting system. Careful attention must also be given to ensure that the cyst arises from the kidney versus the liver (hepatic cyst). Compared to renal masses, renal cysts are round and sharply demarcated with smooth walls; they are anechoic and will likely demonstrate posterior acoustic enhancement (Hindman 2016).

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Keywords/Tags: Renal cyst, hydronephrosis, posterior acoustic enhancement

10. EXPLANATION

C. Perform a bedside ultrasound of the aorta as well as a FAST exam. This patient is at significant risk for abdominal aortic aneurysm (AAA) due to his male gender, age, and smoking history. Furthermore, his diaphoresis, hypotension, and compensatory tachycardia are concerning for an acute leak/rupture. He needs timely diagnosis, which is best accomplished by bedside POCUS and immediate surgical management. While it can be daunting to rely on one's own bedside ultrasound in an undifferentiated patient with flank pain, especially when considering the potential of a vascular emergency such as AAA, studies have shown that emergency physicians can safely rely on their own POCUS as an *initial* imaging modality, with the option to obtain additional imaging if needed based on clinical judgement (Constantino 2005; Dent 2007; Kuhn 2000). In a multicenter, randomized controlled trial by Smith-Bindman, it was concluded that POCUS as the initial imaging modality in patients with suspected nephrolithiasis was associated with a lower cumulative risk of radiation, without significant difference in high-risk diagnoses with complications, serious adverse events, pain scores, return ED visits, or hospitalizations. Consider alternative diagnoses that may be renal colic mimics (see Table 8.2).

Choice A is incorrect because while a CT with IV contrast would also provide the same information, it would likely result in a delay in his care. Choice B is incorrect because there is no evidence of renal obstruction necessitating urology consultation. Choice D is incorrect because while an ECG, CXR, and cardiac markers are appropriate if a cardiac etiology is suspected, this patient's presentation is more concerning for an aortic emergency.

Table 8.2 **RENAL COLIC MIMICS**

- **Gynecologic**
  - **Hemorrhagic cyst**
  - **Dermoid cyst**
  - **Endometrioma**
  - **Ovarian neoplasm**
  - **Ovarian torsion**
  - **Fibroid**
  - **Ectopic pregnancy**
  - **Pelvic inflammatory disease**
- **Gastrointestinal**
  - **Appendicitis**
  - **Diverticulitis**
  - **Biliary disorders**
  - **Pancreatitis**
  - **Small bowel obstruction**
- **Urological**
  - **Pyelonephritis**
  - **Urinary tract infection**
- **Vascular**
  - **Abdominal aortic aneurysm +/- aortic dissection**
  - **Renal artery thrombosis**
  - **Renal infarction**
  - **Mesenteric artery dissection or embolism**
  - **Intraperitoneal or retroperitoneal hemorrhage**
- **Musculoskeletal**
  - **Mechanical low back pain**
  - **Fractures**
- **Miscellaneous**
  - **Herpes zoster infection (Shingles)**

Adapted from: Graham A, Luber S, Wolfson AB. Urolithiasis in the emergency department. *Emerg Med Clin North Am*. 2011;29(3):519-538. doi:10.1016/j.emc.2011.04.007.

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Smith-Bindman R, Aubin C, Bailitz J, et al. Ultrasonography versus computed tomography for suspected nephrolithiasis. *N Engl J Med*. 2014;371(12):1100–1110.

Keywords/Tags: Abdominal aortic aneurysm, normal renal ultrasound, renal colic mimics

11. EXPLANATION

D. Obtain a CT of the abdomen and pelvis and request Urology consultation or outpatient referral. The ultrasound image demonstrates a solid renal mass concerning for renal cell carcinoma (arrows), which would require further imaging and workup. This patient unlikely needs inpatient workup; however, it would be appropriate to consult Urology to schedule a timely appointment for an outpatient diagnostic biopsy. The patient's treatment plan will be based on the pathology results. Choice A would be appropriate if the diagnosis was cystitis or prostatitis, but not in this case. Items in choice B may be useful but would not be the best next steps in management, as the patient is hemodynamically stable. In addition, this choice fails to address the further workup required to evaluate the renal mass. Choice C would be appropriate in a patient with a symptomatic ureteral stone, which is not the case in this scenario.

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Keywords/Tags: Renal mass, renal cell carcinoma, renal malignancy, gross hematuria

12. EXPLANATION

B. Acute urinary retention (AUR) due to prostatic enlargement. The patient presents with AUR over 24 hours, most often secondary to benign prostatic hyperplasia (BPH) in males. The ultrasound finding demonstrates a distended urinary bladder, and prompt bladder decompression by catheterization is indicated. The image also suggests an enlarged prostate, which protrudes into the bladder resulting in a distorted neck. Note that intravesical prostatic protrusion should not be confused with a bladder mass. Therefore, it is important to also always scan in the orthogonal plane, to ensure the protrusion is arising from prostate instead of in the bladder.

Ultrasound may also be used to assess bladder volume and can be a useful adjunct to assess for correct catheter placement. In addition to BPH, other (less common) obstructive causes of AUR include urethral stricture, urethral urolithiasis, phimosis, paraphimosis, and cancer (bladder or prostate). Nonobstructive etiologies include medications, neurologic disease, infection, and trauma (Thomas 2004).

Learning Points: Ultrasound can rapidly identify AUR, and in select cases may help identify the cause of retention, such as obstruction from BPH.

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Keywords/Tags: Bladder, prostate, urinary retention

13. EXPLANATION

C. Placing the probe just cephalad to the pubic symphysis, visualize the urinary bladder. Ensure to scan thoroughly in the sagittal and transverse planes to assess for free fluid. Bedside ultrasound can be used to rapidly identify free fluid in various body cavities, including the pericardial, pleural, and peritoneal spaces. Ultrasonography of the pelvis is frequently utilized to assess pelvic anatomy, as well as identification of free fluid in the pelvis. A proper evaluation typically focuses on visualization of the urinary bladder in two axes.

The urinary bladder is visualized by placing a low-frequency probe on the skin at midline, just cephalad to the pubic symphysis. A full urinary bladder is typically easily visualized at this location. An unfilled bladder may require the examiner to direct the ultrasound beam further caudally into the pelvis.

The normal urinary bladder appears as a thin-walled, well-circumscribed organ containing urine, which appears anechoic. To achieve the longitudinal (sagittal) axis, the probe marker is oriented cephalad, and a thorough evaluation includes sweeping the probe from the patient's right to the left, thereby assessing the bladder from end to end (Figure 8.23a). To achieve the transverse axis, the probe marker is oriented to the patient's right, and a thorough evaluation includes sweeping the probe from superior to inferior (Figure 8.23b).

Free fluid in male patients appears in the recto-vesical pouch, which is the pocket that lies between the rectum and the urinary bladder (Figure 8.23c). In female

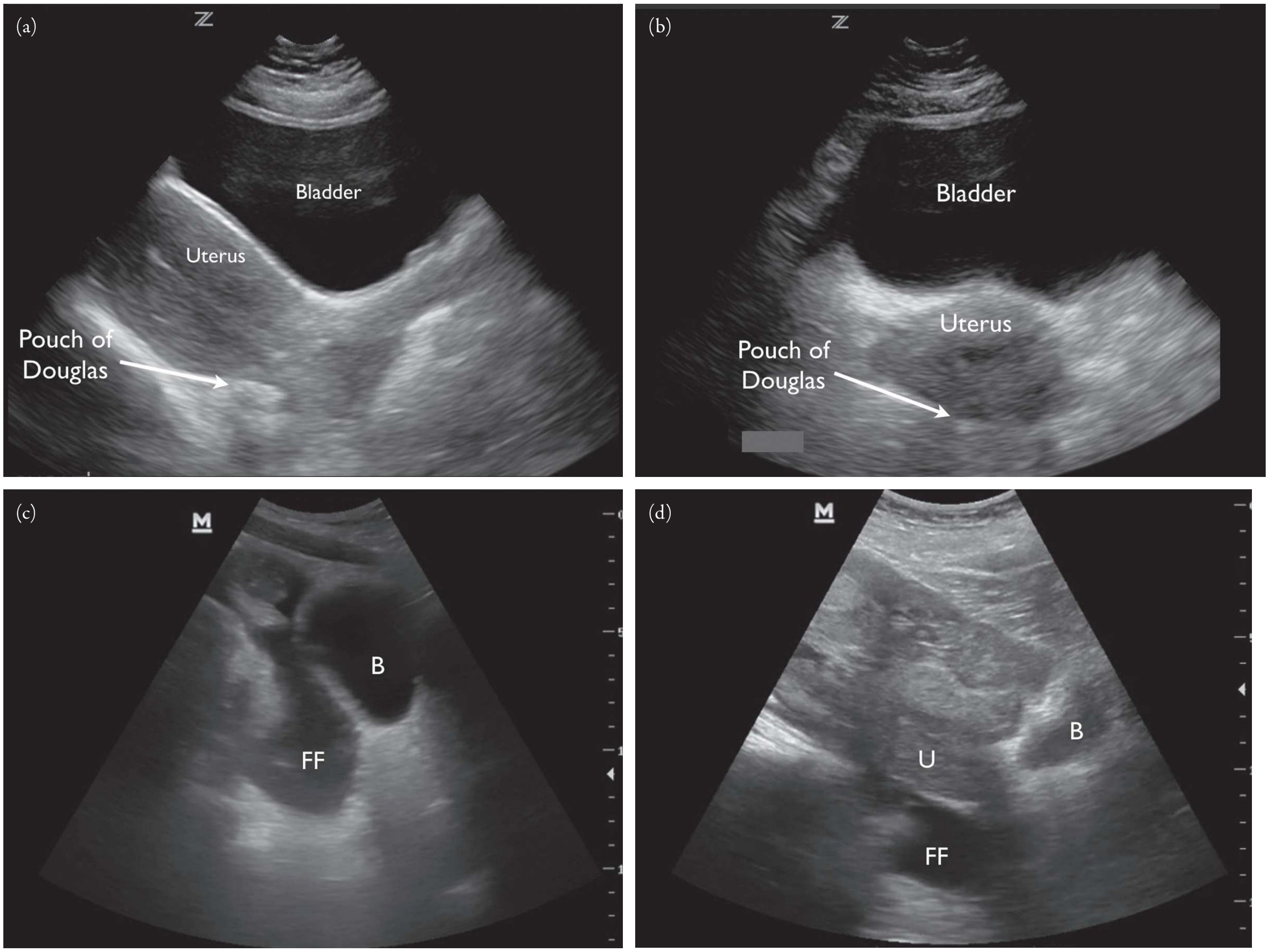

Figure 8.23 (a) **Normal female pelvic view, long axis view.** (b) **Normal female pelvic view, short axis view.** (c) **Long axis view of male pelvis with free fluid in the recto-vesical pouch.** B = bladder, FF = free fluid. (d) **Long axis view of female pelvis with free fluid in the pouch of Douglas.** B = bladder, FF = free fluid, U = uterus.

patients who have a uterus, free fluid collects in the recto-uterine pouch of Douglas (posterior cul de sac) and/or the shallower vesico-uterine pouch (anterior cul de sac) (Figure 8.23d).

Learning Points: Proper assessment of free fluid in the pelvis requires thorough ultrasound evaluation of the bladder and its surrounding structures in the transverse and sagittal planes.

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Kuenssberg Jehle Von D, Stiller G, Wagner D. Sensitivity in detecting free intraperitoneal fluid with the pelvic views of the FAST exam. *Am J Emerg Med*. 2003;21(6):476–478.

Keywords/Tags: Bladder, FAST, acquisition, abdominal free fluid

14. EXPLANATION

A. Abnormal PVR. The patient is experiencing detrusor-sphincter dyssynergia (i.e., neurogenic bladder) very likely due to her history of multiple sclerosis. The ultrasound shows a significantly distended bladder with a PVR of 673 mL. This is typically a gradual process that often results in chronic urinary retention, and the diagnosis may be confirmed by obtaining a PVR volume via bladder catheterization, or via bladder ultrasound (Ghani 2008). A study by Hvarness in 2002 found ultrasound to be accurate in predicting PVR volume but, depending on the calculation method used, can under- or overestimate with errors in the range of –56% to +58.8%.

It is important to note that there is no standardized acceptable normal range for PVR. However, most published sources on the topic suggest that a PVR <50 mL is typical in most healthy, asymptomatic patients.

Additionally, a PVR of 50 to 100 mL is also acceptable in many symptomatic patients and is common in patients over age 65. A PVR of 100 to 200 mL requires clinical correlation, and a value >200 mL is generally considered abnormal (Kelly 2004).

Learning Points: Bladder emptying: <50 mL PVR normal. <100 mL PVR is acceptable in patients >65.

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Kelly CE. Evaluation of voiding dysfunction and measurement of bladder volume. *Rev Urol*. 2004;6(Suppl 1):S32–S37.

Keywords/Tags: Bladder, bladder volume, postvoid residual, urinary retention

15. EXPLANATION

C. In transverse plane, measure the bladder width (right to left) and anterior-posterior depth (near field to far field on screen). Then rotate the probe 90° and measure the bladder's craniocaudal height in sagittal plane. A proper calculation of urinary bladder volume requires three measurements. Scanning is performed via a transabdominal approach in the transverse and sagittal planes, to determine the bladder H, W, and D.

In the transverse plane, W and D correspond to the greatest right to left measurement (W) and the greatest anterior-posterior measurement (D), respectively (Figure 8.24a). Subsequently, the probe is rotated 90° to the sagittal plane. In this orientation, the greatest superior-inferior (cranio-caudal) measurement will correspond to the bladder H (Figure 8.24b).

Most modern ultrasound machines are now equipped with software that automatically calculates bladder volume once these three measurements are taken. In the event that such software is not available, an alternate method used to determine volume is the formula: H × W × D × *correction coefficient* (Dicuio 2005).

The correction coefficient may vary with the various bladder shapes; however, most urology and urogynecology texts recommend using 0.72 as the correction coefficient. Using 10 different formulas from the literature, Liu-Ing et al. compared actual bladder volume to ultrasound calculated bladder volume and additionally assessed the impact of bladder shape on the accuracy of bladder volume estimation. Ultimately, the study found that a coefficient of 0.72 coefficient was accurate when not considering bladder shape. The value of 0.72 is a correction factor for the nonspherical shape of a full bladder, and the approximate error rate of this formula is 21%.

Learning Points: A quick manual formal to calculate bladder volume is H × W × D × 0.7.

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Bih LI, Ho CC, Tsai SJ, Lai YC, Chow W. Bladder shape impact on the accuracy of ultrasonic estimation of bladder volume. *Arch Phys Med Rehabil*. 1998;79(12):1553–1556.

Birch NC, Hurst G, Doyle PT. Serial residual volumes in men with prostatic hypertrophy. *Br J Urol*. 1988;62(6):571–575.

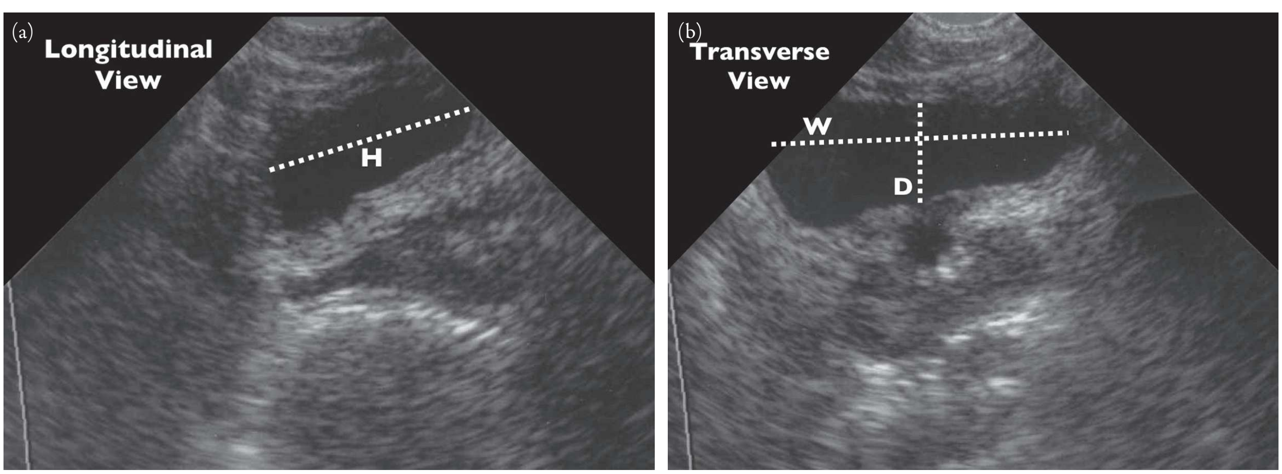

Figure 8.24 (a) **Transverse view of bladder.** L = length of bladder and D = diameter of bladder. (b) **Postvoid residual calculation.** Sagittal view with sup/inferior measurement (Height).

Dicuio M, Pomara G, Menchini Fabris F, Ales V, Dahlstrand C, Morelli G. Measurements of urinary bladder volume: comparison of five ultrasound calculation methods in volunteers. *Arch Ital Urol Androl*. 2005;77(1):60–62.

Keywords/Tags: Bladder, bladder volume, acquisition, postvoid residual

16. EXPLANATION

A. Ultrasound of the kidneys and urinary bladder. The patient presents with suspected ureterolithiasis, and therefore the most appropriate initial diagnostic step is to perform an ultrasound to evaluate for hydronephrosis. A finding of hydronephrosis (distention of the renal calyces and pelvis with urine) supports the diagnosis of an obstructing kidney stone (Figure 8.22).

It should be noted that an AAA may mimic renal stones, and therefore the examiner should consider scanning aorta in patients presenting with renal colic or flank pain who are at increased risk for AAA.

A multicenter study by Smith-Bindman in 2014 randomized patients presenting to the ED with suspected nephrolithiaisis to undergo either (a) an initial diagnostic ultrasound performed by an emergency physician (point-of-care study), (b) a formal ultrasound interpreted be a radiologist, or (c) a CT scan of the abdomen and pelvis. A total of 2,776 patients were randomly assigned into one of these 3 groups. Subsequent patient management was at the discretion of the physician.

The study ultimately revealed that if a POCUS was used as the initial diagnostic study of choice, the diagnosis of renal colic (when present) was quickly established, resulting in a reduced length-of-stay in the ED. In addition, there was an approximately 50% reduction of mean radiation exposure in the ultrasonography group as compared to the CT group.

The study did not prevent the treating physician from ordering further imaging and therefore did not suggest that patients should undergo ultrasound imaging alone if results are inconclusive.

The 3 groups were also found to have no difference in 30-day incidence of high-risk diagnoses that could be related to missed or delayed diagnosis. Additionally, secondary outcomes such as pain scores, hospital admissions, and ED readmissions during the 6-month follow-up did not differ significantly among the groups.

Choice B is incorrect since the patient denies any urinary retention. Choice C is incorrect, as POCUS can reduce radiation and time to diagnosis as compared to CT. Choice D is incorrect since the patient did not endorse any genital symptoms.

Learning Points: Initial POCUS is associated with lower cumulative radiation exposure than initial CT, without significant differences in high-risk diagnoses with complications, serious adverse events, pain scores, return ED visits, or hospitalizations.

REFERENCE

Smith-Bindman R, Aubin C, Bailitz J, et al. Ultrasonography versus computed tomography for suspected nephrolithiasis. *N Engl J Med*. 2014;371(12):1100–1110.

Keywords/Tags: Renal, nephrolithiasis, hydronephrosis, AAA

17. EXPLANATION

D. Right ureteral obstruction. The ultrasound of the bladder reveals unilateral ureteral jets. Symptomatic ureteral obstruction can occur without hydronephrosis, and absence of ureteral jets on the symptomatic side can help identify this. To best visualize jets, the bladder is visualized with the probe placed in a transverse position at the level of the trigone (Dubbins 1981). Color or power Doppler mode may be utilized to detect urine flowing into the bladder from the ureters, typically flowing in an antero-medial direction. Although some sources report that an absent jet suggests ureteral obstruction, it is important to emphasize that accurate evaluation of jets may require from 10 to 45 minutes. Cvitković, et al. found that absence of ureteral jets was seen in 11% of patients with no hydronephrosis and in 89% of patients with obstructive hydronephrosis from calculi. Regardless of the etiology of hydronephrosis, there was a marked decrease in the number of jets observed in the affected side compared to the normal side (<1 to 4–5 jets per minute observed). Therefore, while absence or reduction of ureteral jets for diagnosing ureteral obstruction is not sensitive, it is specific.

Learning Points:
- Ureteral obstruction does not always present with hydronephrosis.
- Ureteral jets can be a helpful adjunct in identifying ureteral obstruction.

REFERENCES

Cvitković Kuzmić A, Brkljacić B, Rados M, Galesić K. Doppler visualization of ureteric jets in unilateral hydronephrosis in children and adolescents. *Eur J Radiol*. 2001;39(3):209–214.

Dubbins PA, Kurtz AB, Darby J, Goldberg BB. Ureteric jet effect: the echographic appearance of urine entering the bladder: a means of identifying the bladder trigone and assessing ureteral function. *Radiology*. 1981;140(2):513–515.

Keywords/Tags: Bladder, renal, nephrolithiasis, ureteric jet, hydronephrosis

18. EXPLANATION

D. Transabdominal ultrasound to evaluate the uterus and pelvic contents. The urinary bladder is located anteriorly in the pelvis. When fully distended with urine, it provides an acoustic window that is ideal to view structures in the pelvis with transabdominal scanning. In females, the bladder serves as an acoustic window to visualize the uterus, cervix, and (occasionally) the ovaries. In males, the prostate and seminal vesicles are much more easily visualized with a full bladder.

In addition to these anatomic structures, pathologic findings may also be more readily identified using a full urinary bladder. Examples of such pathology include intraperitoneal free fluid, uterine fibroids, prostatic hypertrophy, bladder tumors, bladder calculi, or diverticulae.

Note that during transvaginal scanning (especially in the evaluation of early pregnancy), it is actually preferred that the patient voids prior to the ultrasound examination. A full urinary bladder may result in a difficult exam due to the displacement of relevant structures on the screen. Benacerraf et al. showed that, in institutions that have transvaginal scanning readily available, a full bladder may not be necessary for transabdominal ultrasound. If pathology is not easily recognized on transabdominal scanning, they proceeded immediately to transvaginal ultrasound. They feel this would reduce patient discomfort and decrease time to imaging as they do not have to wait for the bladder to fill. However, this is institution dependent and in general using the bladder as an acoustic window will help clinicians see pelvic structures during a transabdominal ultrasound exam.

Regarding calculation of urinary bladder volumes, an accurate estimate is typically made when the bladder is not collapsed. However, it is not imperative that the bladder be fully distended prior to performing the bladder volume exam.

Edge artifact refers specifically to a hypoechoic shadow that extends down from the edges of a curved reflector, such as the urinary bladder. This entity occurs due to the refraction of the ultrasound beam as it strikes the surface of the curved reflector. Edge artifact would not be limited simply due to the presence of a full urinary bladder.

Learning Points: When fully distended with urine, the urinary bladder provides an acoustic window that is ideal to view structures in the pelvis with transabdominal scanning.

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Benacerraf BR, Shipp TD, Bromley B. Is a full bladder still necessary for pelvic sonography? *J Ultrasound Med*. 2000;19(4):237–241.
Kim SH, Cho JY, Lee HJ, Sung CK, Kim SH. Ultrasound of the urinary bladder, revisited. *J Med Ultrasound*. 2007;15(2):77–90.
Yuen JSP, Ngiap JTK, Cheng CWS, Foo KT. Effects of bladder volume on transabdominal ultrasound measurements of intravesical prostatic protrusion and volume. *Int J Urol*. 2002;9(4):225–229.

Keywords/Tags: Bladder, acquisition, acoustic window

19. EXPLANATION

D. Discharge home with a urine strainer and Urology follow-up. The ultrasound finding demonstrated in Figure 8.13a is the "twinkling artifact" located approximately at the level of the left ureterovesical junction (UVJ). This is a sonographic artifact located behind calcifications of ureteral calculi (or other calcific, highly reflective objects) when color Doppler is applied. It will appear as a multicolored high intensity signal, similar to signal produced by turbulent flow. Based on pulse wave Doppler analysis, this artifact is felt to be due to the ultrasound system interpreting the signal as Doppler shifts. This artifact may also be associated with color comet-tail artifact, which, similar to grey-scale comet-tail artifact, occurs when an ultrasound beam encounters 2 strong parallel reflectors (Figure 8.13b). When the ultrasound beam reflects back and forth between the 2 strong parallel reflectors, the ultrasound transducer interprets the sound waves as returning from deep structures since it took longer for the wave to return. This leads to the "tail" like appearance from numerous reverberation signals that the transducer is receiving. The twinkling artifact has a sensitivity and specificity of 90% and 100%, respectively, for nephrolithiasis at the UVJ level.

Given that this finding confirms the diagnosis of nephrolithiasis and the patient is comfortable, she can be discharged home with outpatient Urology follow-up; no further imaging or consultation is indicated at this time.

Learning Points: Color Doppler can be used to assess for the twinkle artifact, which can be seen in ureterolithiasis and is more sensitive for detection of small stones.

REFERENCES

Aytaç SK, Ozcan H. Effect of color Doppler system on the twinkling sign associated with urinary tract calculi. *J Clin Ultrasound*. 1999;27(8):433–439.
Ripollés T, Martínez-Pérez MJ, Vizuete J, Miralles S, Delgado F, Pastor-Navarro T. Sonographic diagnosis of symptomatic ureteral calculi: usefulness of the twinkling artifact. *Abdom Imaging*. 2013;38(4):863–869.
Tchelepi H, Ralls PW. Color comet-tail artifact: clinical applications. *AJR Am J Roentgenol*. 2009;192(1):11–18.

Keywords/Tags: Nephrolithiasis, twinkle artifact

20. EXPLANATION

C. Irrigate the catheter. The ultrasound image demonstrates correct placement of the Foley balloon (hyperechoic rim with a hypoechoic center) within the bladder. There is also evidence of a moderate amount of urine that is not draining appropriately as mentioned in the question stem.

Ultrasound can be a useful adjunct to assess for correct placement of a Foley catheter, as well as to assess bladder volume when acute urinary retention is suspected. If the Foley balloon is difficulty to visualize, a small amount of agitated saline can be flushed through the Foley while simultaneously evaluating the bladder with ultrasound.

For difficult Foley placement, ultrasound-guided Foley placement using a hydrophilic guidewire has been described (Joseph 2018).

Given that ultrasound has confirmed proper location of the Foley balloon, the next best step is to flush the catheter with sterile saline to assess for patency and break up any sediment/clot, or abnormal lie of Foley tip, that may be preventing urine outflow (Wu 2015).

Learning Points: Bedside ultrasound can be used to assist with troubleshooting foley catheter malfunction or misplacement.

REFERENCES

Joseph R, Huber M, Leeson B, Leeson K. Ultrasound-guided placement of a Foley catheter using a hydrophilic guide wire. *CPCEM*. 2018;2(2):143–146.

Wu T. Finding the foley. *Emergency Physicians Monthy*. Janurary 14, 2015. http://www.epmonthly.com.

Keywords/Tags: Foley placement, bladder

21. EXPLANATION

B. Reassure that current kidney stone is likely to pass on its own. The ultrasound image demonstrates mild hydronephrosis (pelviectasis) suggestive of an obstructing ureteral stone. While not 100% specific, there is good evidence that patients with none or mild hydronephrosis on ultrasound are significantly more likely to have ureteral stones <5 mm and will likely pass them without need for surgical intervention (Goertz 2010).

Since the patient has a history of nephrolithiasis and clinically she is presenting with ureteral obstruction, CT is not warranted in this case. The patient can be safely counseled that her kidney stone has a high probability of passing on its own and it is reasonable to discharge her home with oral pain medications and Urology follow-up in 1 to 2 weeks (Jendeberg 2017).

Learning Points: In patients with suspected ureteral stone, those with none or mild hydronephrosis are significantly more likely to have ureteral stones < 5 mm, which have a high probability of passing without need for surgical intervention.

REFERENCES

Goertz JK, Lotterman S. Can the degree of hydronephrosis on ultrasound predict kidney stone size? *Am J Emerg Med*. 2010;28(7):813–816.

Jendeberg J, Geijer H, Alshamari M, Cierzniak B, Lidén M. Size matters: the width and location of a ureteral stone accurately predict the chance of spontaneous passage. *Eur Radiol*. 2017;27(11):4775–4785.

Keywords/Tags: Nephrolithiasis, hydronephrosis

22. EXPLANATION

A. Recommend pain control and referral to primary care physician and nephrologist. The ultrasound demonstrates numerous simple cysts throughout the left kidney. Given his family history, this is concerning for autosomal dominant polycystic kidney disease (ADPKD). In patients between the ages of 15 and 29 with a family history of ADPKD, identification of at least 2 renal cysts, unilateral or bilateral, is very sensitive and specific for this diagnosis.

While the diagnosis of ADPKD is not usually made in the ED, it is associated with numerous complications that the emergency provider should consider as a reason for the acute symptoms. Specifically, renal manifestations include varying degrees of kidney injury, recurrent urinary tract infections, kidney stones, and hematuria (from cyst rupture). Extrarenal manifestations include flank pain, hypertension, cardiac hypertrophy, hepatic cysts, intracranial aneurysm, diverticulitis, and abdominal hernias. It is also important to note that patients with advanced renal cell carcinoma can also have similar-appearing findings on limited bedside ultrasound, and this should be considered in the differential diagnosis, especially in older patient populations.

The patient described in the question has visible hematuria consistent with cyst rupture. While nephrolithiasis is common in these patients, it is unlikely to cause gross hematuria. He is well appearing at this time, with a benign exam, and his urinalysis does not demonstrate any signs of an acute infection. No imaging is necessary at this time. However, the patient should be counseled regarding the high suspicion for ADPKD and referred to both a primary care physician and Nephrology for further diagnostics and therapy.

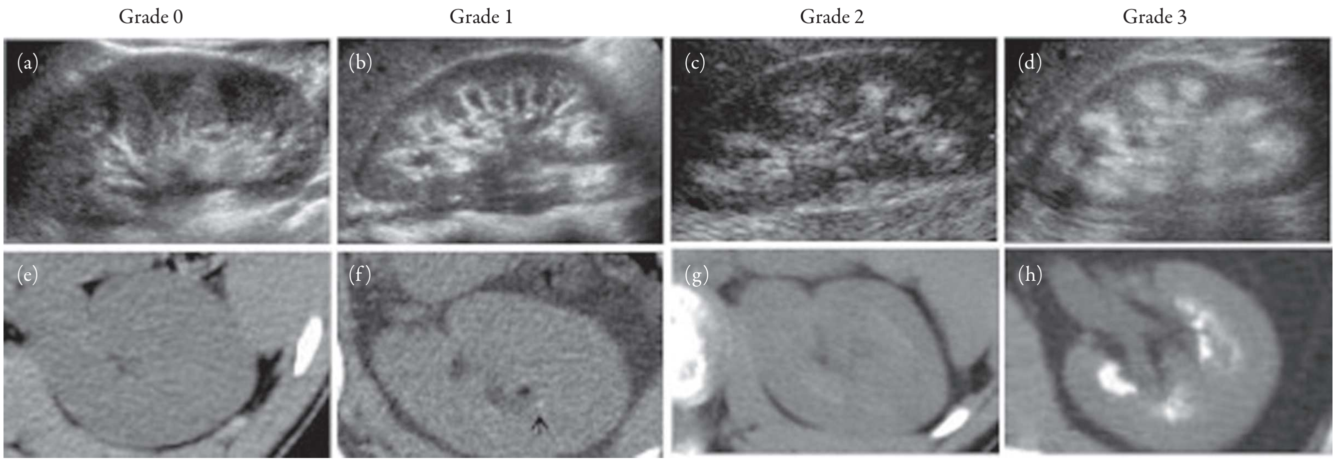

Figure 8.25 **Ultrasound grading of the severity of nephrocalcinosis.** Grade 1 = mild echogenicity around the medullary pyramid borders; grade 2 = moderate echogenicity around and inside pyramids; grade 3 = severe echogenicity of entire pyramids.

Learning Points: Patients with ADPKD are at risk for numerous complications including urinary tract infection, ureteral stones, and hematuria (cyst rupture) which should be considered when evaluating these patients who present to the emergency department with flank pain, abdominal pain, or hematuria. If no acute issue is identified, all of these patients should be referred as outpatient for further diagnostics and therapy.

REFERENCES

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Srivastava A, Patel N. Autosomal dominant polycystic kidney disease. *Am Fam Physician*. 2014;90(5):303–307.

Keywords/Tags: Polycystic kidney disease

23. EXPLANATION

C. Referral to primary care physician for further medical workup. The ultrasound image demonstrates increased echogenicity around and inside the renal pyramids consistent with moderate nephrocalcinosis. Ultrasound grading of the severity of nephrocalcinosis is as follows: grade 1, mild echogenicity around the medullary pyramid borders; grade 2, moderate echogenicity around and inside pyramids; grade 3, severe echogenicity of entire pyramids (see Figure 8.25). Compared to CT, ultrasound is superior in detection of mild to moderate nephrocalcinosis and is now the preferred method for evaluation for this disease entity (Boyce 2013).

Nephrocalcinosis refers to increased calcium deposition within the kidneys. These deposits tend to occur primarily in the area of the renal pyramids, termed medullary nephrocalcinosis. This disease entity can occur bilaterally or may only involve a single kidney. It is often found incidentally on unrelated medical imaging and is a manifestation of disorders that lead to hypercalcemia and or hypercalciuria. The differential diagnosis is quite broad in adults; however, the most common causes of nephrocalcinosis are primary hyper/hypoparathyroidism, distal renal tubular acidosis, and medullary sponge kidney, as well as medications including acetazolamide, amphotericin, and triamterene.

In the setting of an otherwise asymptomatic patient, no further workup is indicated in the ED; however, these patients should all be referred to a primary care physician for further workup of an underlying medical condition.

Learning Points: Asymptomatic patients with ultrasound findings concerning for nephrocalcinosis should be referred to primary care for further work up of underlying medical condition.

REFERENCES

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Monk RD, Bushinsky DA. Nephrolithiasis and nephrocalcinosis. In: Johnson RJ, Feehally J, eds. *Comprehensive Clinical Nephrology*. 2nd ed. St. Louis, MO Mosby; 2003:731–734.

Keywords/Tags: Nephrocalcinosis

24. EXPLANATION

D. Provide reassurance and refer to primary care physician for follow-up. The ultrasound image demonstrates a simple cyst located in the cortex of the kidney. The cyst can be described as anechoic, homogenous, with thin and smooth walls, and would be a type I lesion according to the Bosniak classification system (Figure 8.26, Table 8.3).

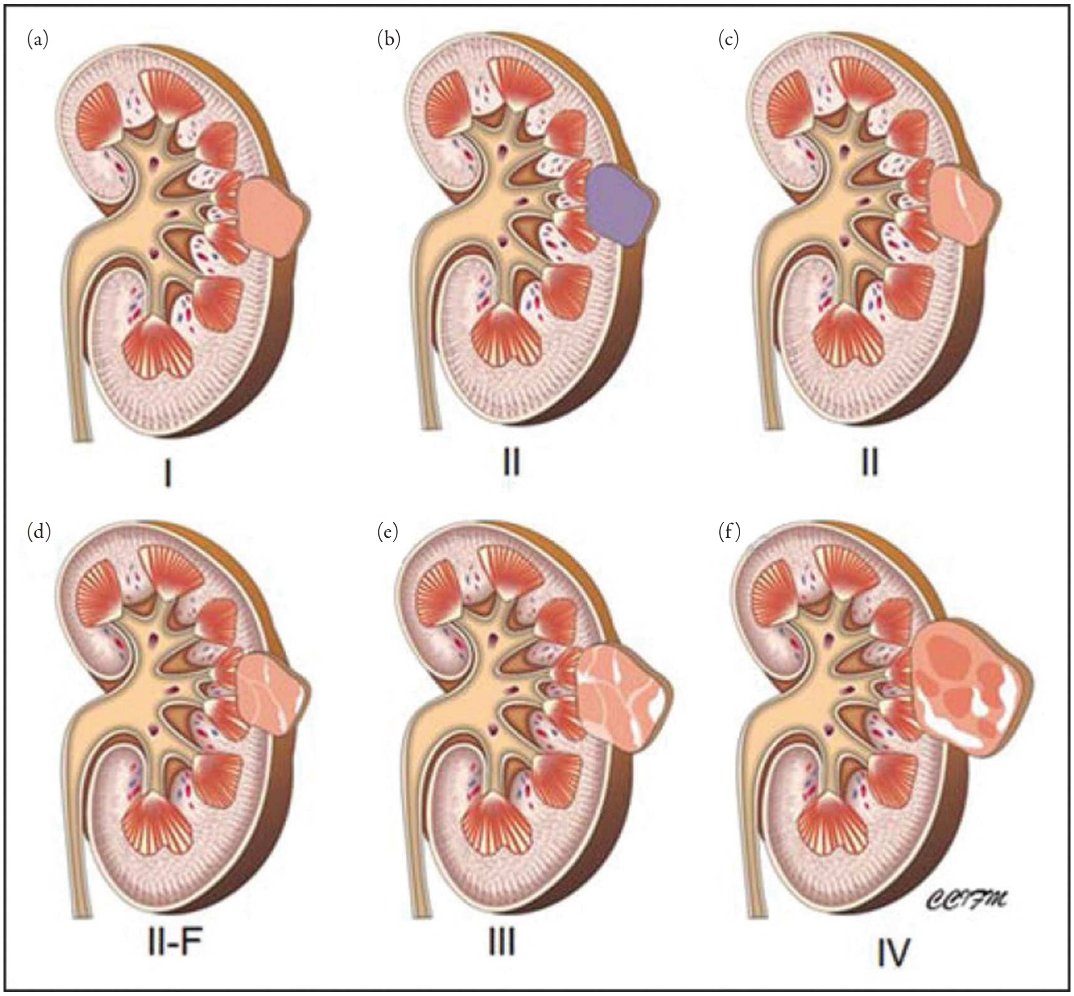

Figure 8.26 **Bosniak Classification.** Adapted from Figure 1, Muglia VF, Westphalen AC. Bosniak classification for complex renal cysts: history and critical analysis. *Radiol Bras.* 2014;47(6):368-373. doi:10.1590/0100-3984.2013.1797.

Table 8.3 IMAGING FINDINGS AND BOSNIAK CLASSIFICATION WITH AND WITHOUT CONTRAST USING CT SCAN

TYPE	IMAGING FEATURES WITHOUT CONTRAST	CT CONTRAST ENHANCEMENT FEATURES
I	Thin margins, sharp delineation with the renal parenchyma, thin and smooth walls, homogeneous	No contrast enhancement
II	Presence of one or few thin septations, small and fine calcifications; hyperdense cysts measuring up to 3.0 cm	No contrast enhancement, or no measurable or perceptible enhancement of septa
IIF	More complex lesions which cannot be included in category II or III. Multiple septa. Walls or septa with nodular or irregular calcifications	Absent, dubious, or hair-like enhancement
	Hyperdense cysts >3.0 cm or with only 25% of their walls visible (exophytic)	
III	Thick-walled cystic lesion, septum irregularity, and heterogeneous septum and wall and/or contents. Gross and irregular calcifications with measurable enhancement	Wall and/or septum enhancement
IV	Lesions with all the findings of category III, and solid component, soft parts, independent of finding of wall or septa	

Adapted from: Muglia VF, Westphalen AC. Bosniak classification for complex renal cysts: history and critical analysis. *Radiol Bras*. 2014;47(6):368–373. doi:10.1590/0100-3984.2013.1797.

The Bosniak classification for renal cysts was developed in the 1980s as an attempt to standardize the description and management of complex renal lesions. Based on classification of the renal lesion, the likelihood of malignancy can also be predicted. The percentage of chance of malignancy is 1.7% for Bosniak I, 18.5% for Bosniak II, 33.0% for Bosniak III, and 92.5% for Bosniak IV (McGuire 2010). While the Bosniak classification was initially described and validated with CT imaging, newer data suggests that ultrasound may be sufficient to follow renal cysts that are minimally complex (Bosniak I and II).

Given the ultrasound demonstrates a Bosniak I lesion in the left kidney, the patient can be reassured that this finding is very unlikely to be malignant and she can be referred to a primary care provider for follow-up in the upcoming weeks for formal outpatient renal ultrasound.

Learning Points: The Bosniak classification for renal cysts can be used to estimate the likelihood of malignancy based on bedside ultrasound findings. All patients, who have a renal cyst identified incidentally on bedside ultrasound, regardless of Bosniak classification, should be referred to primary care provider for follow up outpatient renal ultrasound.

REFERENCES

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Schoots IG, Zaccai K, Hunink MG, Verhagen PCMS. Bosniak classification for complex renal cysts reevaluated: a systematic review. *J Urol*. 2017;198(1):12–21.

Keywords/Tags: Bosniak classification, renal cyst

25. EXPLANATION

A. Emergent urology consultation. The ultrasound demonstrates a hypoechoic rim of fluid surrounding the right kidney. Given the patient's clinical history and presentation, this is most consistent with a perinephric abscess (Figure 8.27). Urology should be consulted emergently to evaluate the need for surgical or percutaneous intervention.

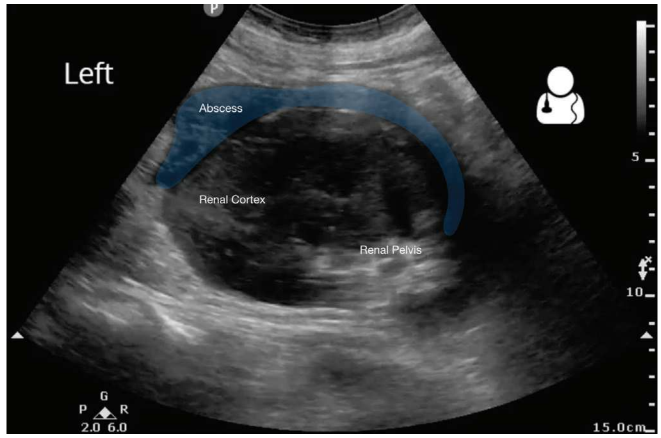

Figure 8.27 **Perinephric abscess.** Adapted from: Smith, BC. UOTW #72. Ultrasound of the Week. July 11, 2016. https://www.ultrasoundoftheweek.com/uotw-72/.

Perinephric abscess is a complication of pyelonephritis with high morbidity and mortality. Important risk factors include immunocompromised states, nephrolithiasis, and diabetes. Symptoms are often identical to that of pyelonephritis (fever, nausea/vomiting, flank/abdominal pain, and urinary symptoms), which often leads to a delayed diagnosis. For this reason, emergency physicians must maintain a high index of suspicion for this condition as it can easily be missed.

Ultrasound can be used as a first-line imaging modality to evaluate for perinephric abscess; however, CT will provide better characterization of the abscess. Small perinephric abscesses (<3 cm) are usually managed with antibiotic therapy alone, while larger abscesses will require percutaneous or surgical drainage.

Learning Points: Perinephric abscess is a complication of pyelonephritis with high morbidity and mortality. Ultrasound can be used as a first line imaging modality, however CT should be considered to better characterize the abscess once identified.

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Smith, BC. UOTW #72. *Ultrasound of the Week*. July 11, 2016. https://www.ultrasoundoftheweek.com/uotw-72/.

Keywords/Tags: Perinephric abscess

9.

PREGNANCY ULTRASOUND

Maria Tamborski, Sarah Medeiros, Daniel Weingrow, and Pamela Dyne

QUESTIONS

1. A G2P1 woman at 8 weeks estimated gestational age (EGA) by last menstrual period (LMP) presents with pelvic cramping. You wish to assess for intrauterine pregnancy (IUP) as well as fetal heart rate. Which probe, exam setting, and scan mode do you use?

A. Linear, OB, M-mode
B. Curvilinear, OB, Doppler
C. Curvilinear, OB, M-mode
D. Linear, OB, Doppler

2. A 28-year-old female, G3P2, presents with a positive home pregnancy test. Her menstrual cycle is irregular, and her last period was 14 weeks ago. Given the EGA, you believe you will be able to visualize the fetus using the transabdominal approach. Which of the following describes the best approach?

A. Curvilinear probe in the longitudinal axis with probe marker toward the pubic symphysis and transverse axis with probe marker to the patient's right
B. Phased array probe in the longitudinal axis with probe marker toward the pubic symphysis and transverse axis with probe marker to the patient's right
C. Curvilinear probe in the longitudinal axis with probe marker cephalic and transverse axis with probe marker to the patient's right
D. Phased array probe in the longitudinal axis with probe marker cephalic and transverse axis with probe marker to the patient's right

3. A 21-year-old female, G1P0, presents with abdominal cramping. She has a positive urine pregnancy test, and her LMP was 6 weeks ago. You want to perform a transabdominal and transvaginal ultrasound to rule out ectopic pregnancy. The patient requests to urinate before the exam. What is your response?

A. Allow her to go to the bathroom; it does not affect your ultrasound results.
B. Perform the transabdominal exam first, allow the patient to use the bathroom, then perform the transvaginal exam.
C. Perform the transvaginal exam first, since you will not be pressing directly on the bladder. Then allow the patient to urinate before the transabdominal exam.
D. Both transabdominal and transvaginal examinations require a full bladder.

4. You are taking care of a G1P0 17-year-old female who is 5 weeks by dates and complaining of pelvic cramping. Her beta-HCG is 2000. You decide to perform a transvaginal ultrasound to look for an IUP. What equipment and procedures are necessary to properly perform this exam?

A. Sterilized endocavitary probe, nonsterile ultrasound gel, chaperone
B. Sterilized endocavitary probe, sterile gel, chaperone
C. Sterilized probe, sterile gel, transducer cover, chaperone, post-exam cleaning with bleach wipes and autoclave
D. Sterilized probe, sterile and nonsterile gel, transducer cover, chaperone, post-exam high-level disinfection

5. A 16-year-old female, G1P0, presents with pelvic cramping. She has a history of abnormal periods. The patient just learned of her pregnancy on this emergency department (ED) visit and is unsure of her last menstrual cycle. The patient refuses pelvic examination or endocavitary ultrasound. At what EGA can an IUP typically be visualized on transabdominal ultrasound?

A. 4 weeks
B. 5 weeks
C. 6 weeks
D. 7 weeks

6. A 32-year-old female who is trying to conceive presents with concerns that she has been told she has a "flipped" uterus. What is associated with the uterus in Figure 9.1a that is not associated with the uterus in Figure 9.1b?

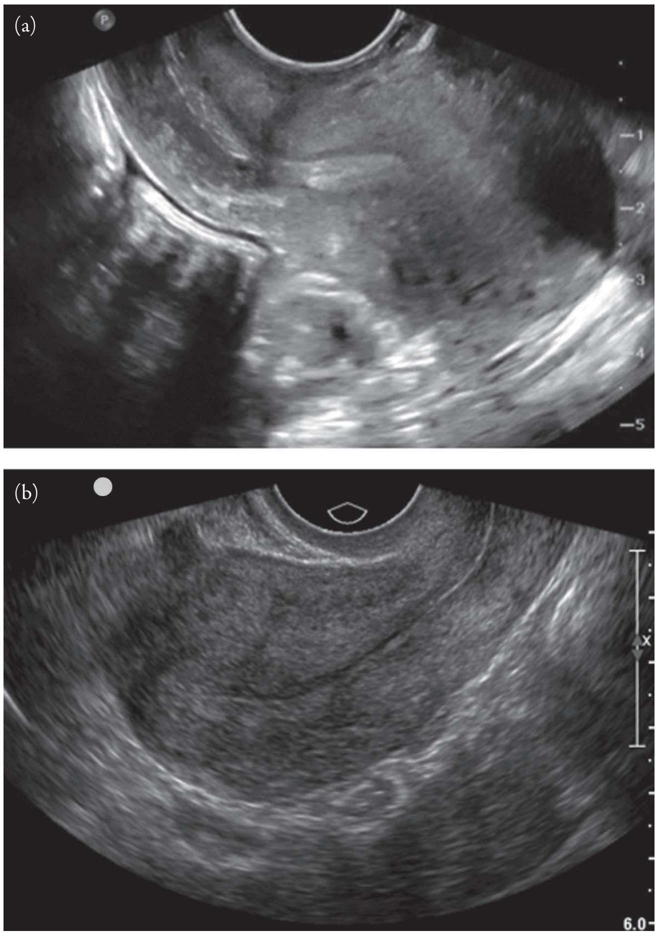

Figure 9.1

A. Uterine prolapse
B. Bladder outlet obstruction
C. Uterine incarceration
D. All of the above

7. A 24-year-old female, G2P0, presents with abdominal cramping. She thinks she is about 5 weeks pregnant, based on LMP, but has not yet visited her OB. You perform a bedside transvaginal ultrasound and obtain the image shown in Figure 9.2. Can you confirm that this patient has an IUP?

A. Yes, there is a gestational sac.
B. Yes, there is a yolk sac.
C. No, there is an ectopic pregnancy.
D. No, a gestational sac is not definitive evidence of an IUP.

Figure 9.2

8. A 23-year-old female, G1P0, who is 3 weeks status post D&C and IUD placement, presents with heavy vaginal bleeding. You perform a transabdominal ultrasound and obtain the image shown in Figure 9.3.
What is the diagnosis?

A. Normal placement
B. IUD expulsion
C. IUD embedment
D. Uterine perforation

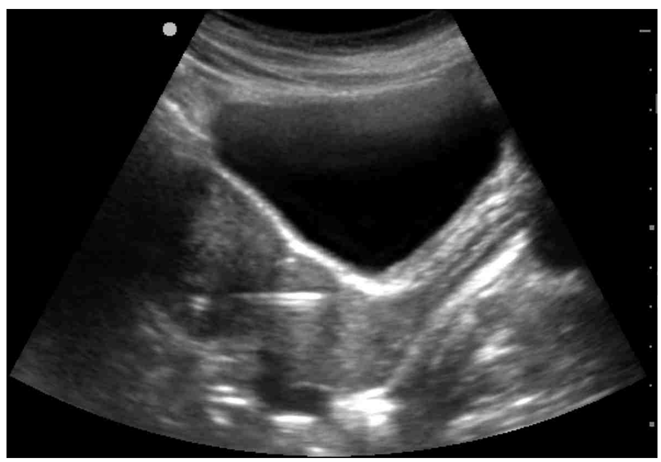

Figure 9.3

9. An 18-year-old female presents with nausea and multiple episodes of nonbloody, nonbilious vomiting. She has a normal appetite, no fever, normal vital signs, and normal pelvic exam. In addition, serial abdominal exams during her visit reveal a benign abdomen. Her labs are notable for a positive urine

pregnancy test. She is not sure of her LMP, as they are generally irregular. You obtain the image shown in Figure 9.4.

Figure 9.4

What is your diagnosis?

A. Acute appendicitis
B. Acute cholecystitis
C. Normal pregnancy with physiologic free fluid
D. Hemoperitoneum

10. A 39-year-old G1P0 Rh+ female presents with pelvic cramping and vaginal spotting. She visited her obstetrician 3 days ago and had a confirmed IUP on pelvic ultrasound. On pelvic exam, there is no significant bleeding and her os is closed. You perform a transabdominal POCUS and obtain the images in Figure 9.5. What is your diagnosis?

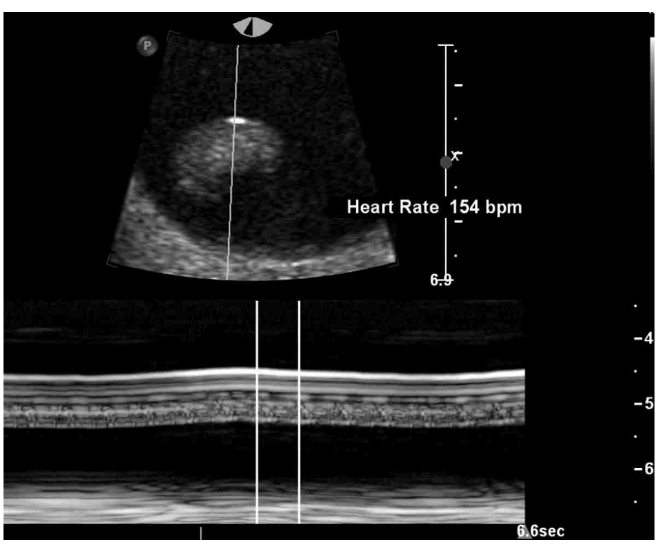

Figure 9.5

A. Normal first trimester ultrasound of an IUP
B. Fetal distress with bradycardia
C. Fetal distress with subchorionic hemorrhage
D. Threatened abortion with normal fetal heart rate

11. A 33-year-old G4P3 female at 6 weeks by LMP presents with pelvic cramping and spotting that began the morning of your evaluation. Her abdominal examination is unremarkable. On pelvic exam, her cervical os is closed; she has some mild uterine tenderness but no adnexal tenderness or fullness. You perform a pelvic ultrasound and obtain the image in Figure 9.6.

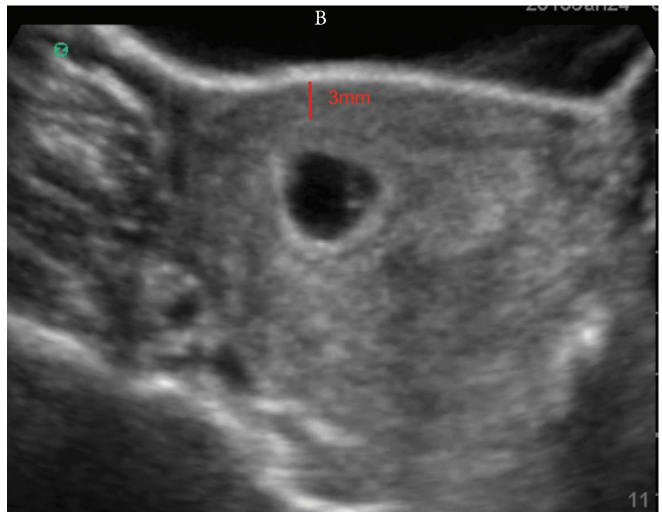

Figure 9.6 B = bladder.

What is your likely diagnosis?

A. Threatened abortion
B. Incomplete abortion
C. Complete abortion
D. Ectopic pregnancy

12. A 19-year-old female, G2P1, presents with right lower quadrant pain. Her LMP was 8 weeks ago. She is afebrile, with a heart rate 110, blood pressure 120/65, and respiratory rate 20. She has mild lower abdominal tenderness on exam, with a normal pelvic exam. Complete blood count is notable for white blood cells of 17 and a hemoglobin of 10. Her urine pregnancy test is positive. A serum quantitative βhCG added on to her blood work returns at 400 mIU/mL. What is the next most appropriate step in management?

A. Discharge her with ObGyn follow-up.
B. Order an outpatient transvaginal ultrasound in 3 days, as the βHCG should be above the discriminatory zone by then.
C. Perform a STAT transvaginal ultrasound.
D. Reassure her and challenge her to eat or drink.

13. A 24-year-old female is brought to the ED after being ejected from a vehicle. The patient loses vital signs moments after arriving in the trauma bay. She appears to be pregnant with the uterine fundus palpated 2 cm below her umbilicus. Cardiopulmonary resuscitation (CPR) is started, a Focused Assessment with Sonography for Trauma (FAST) ultrasound is performed, which is negative but confirms her IUP. What value would be an indication to perform a perimortem caesarian section?

A. Presence of cardiac activity
B. CRL of 7 cm
C. Biparietal diameter of 6.5 cm
D. Femur length of 3 cm

14. It is January and a 30-year-old, healthy, female G3P2 at 12 weeks EGA presents with 3 weeks of productive cough. She denies fever, night sweats, and weight loss and is a nonsmoker. She presents today for blood-tinged sputum. Her vitals are normal except for blood pressure of 140/81. On exam her fundus is palpated at the umbilicus. POCUS echo does not show any evidence of right ventricular strain. Her chest X-ray shows bilateral patchy infiltrates. You perform the pelvic ultrasound shown in Figure 9.7.

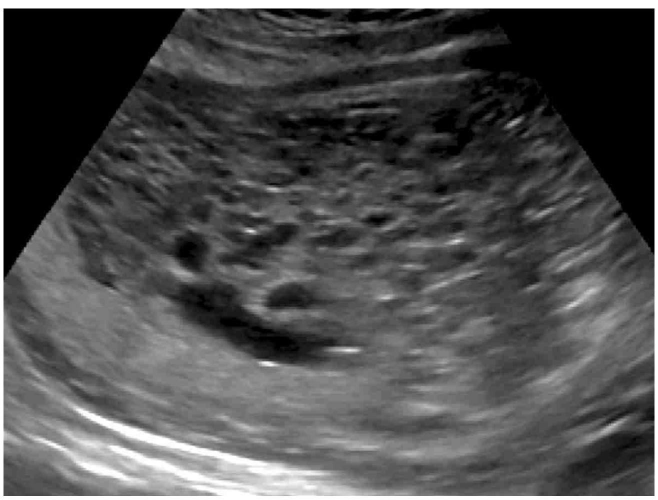

Figure 9.7 From Figure 35.1 of Scoutt LM, Hamper UM, Angtuaco L, eds. *Ultrasound.* Oxford, UK: Oxford University Press; 2017.

What is her diagnosis?

A. Retained products of conception (RPOC)
B. IUP with subchorionic hemorrhage
C. Molar pregnancy
D. Ectopic pregnancy

15. A 26-year-old female G1P1 1 week after spontaneous vaginal delivery presents with continued pelvic pain. The patient had good prenatal care except for premature rupture of membranes by 48 hours. Lochia is slightly pink. Her vital signs are temperature 38.8°C, heart rate 105, blood pressure 110/70, respiratory rate 15. She has moderate suprapubic tenderness on examination. You perform a transabdominal pelvic ultrasound and obtain the image in Figure 9.8.

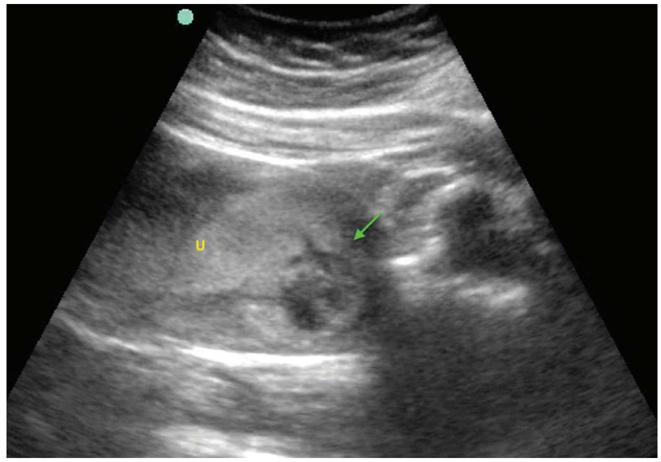

Figure 9.8 U = uterus.

What is the next appropriate step in management?

A. Consult OB for postpartum endometritis and start intravenous (IV) antibiotics.
B. Obtain a computed tomography (CT) scan.
C. Give the patient pain control and fluids, then reassess.
D. Discharge with appropriate OB follow-up.

16. A 20-year-old female G1P0 presents with pelvic cramping and vaginal spotting. She is 8 weeks EGA by LMP. You perform a transvaginal ultrasound and obtain the image in Figure 9.9.

What is the next most appropriate step in management?

A. Discuss expectant management for threatened miscarriage.
B. Consult OB for surgical management for nonviable intrauterine gestation.
C. Consult OB for ectopic pregnancy.
D. Check Rh status and treat with rhoGAM if Rh negative.

17. A 38-year-old female G1P0 at 8 weeks EGA who has recently undergone in vitro fertilization (IVF) treatment presents with pelvic cramping. Her vital signs are stable, and she has suprapubic tenderness to palpation.

Figure 9.9 From Figure 1 of Mohebbi MR, Rosenkrans KA, Luebbert EE, Hunt TT, Jung MJ. *Case Rep Med*. 2011;2011:858241.

A bedside ultrasound is performed and is shown in Figure 9.10.

What is the next appropriate step in management?

A. Order a urinalysis to evaluate for urinary tract infection.
B. Call her obstetrician to arrange prompt outpatient follow-up.
C. Test her RH type and treat with rhoGAM, if positive.
D. STAT consult OB for heterotopic pregnancy.

18. You are caring for a 24-year-old female who presents with acute abdominal pain and a syncopal episode 20 minutes prior to arrival. She looks pale, her blood pressure is 109/80, her heart rate is 120, and she appears clammy. The nurse obtains labs and a spot urine pregnancy test, which is positive. You perform the POCUS exam in Figure 9.11.

Figure 9.11

What is the next best step?

A. Consult ObGyn for an emergent laparotomy.
B. Obtain a transvaginal pelvic ultrasound.
C. Give empiric antibiotics.
D. Obtain a CT abdomen.

19. A 31-year-old G3P2 female who is 6 weeks pregnant by LMP presents with pelvic pain. You perform a transvaginal ultrasound and obtain the image in Figure 9.12.

What is the name for this ultrasound finding?

A. The cheerio sign
B. The ring of fire sign
C. The target sign
D. The Mickey Mouse sign

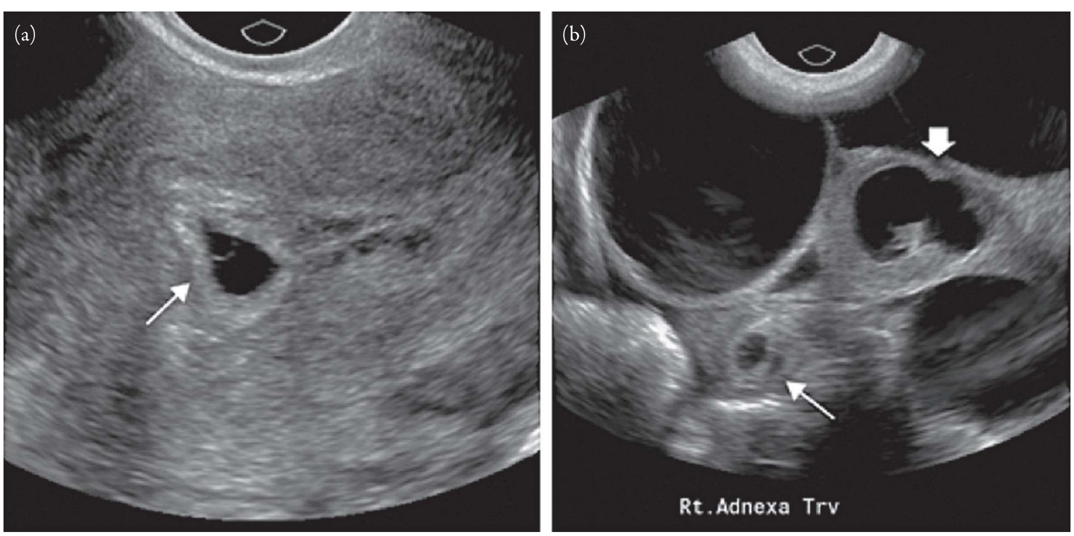

Figure 9.10 Adapted from Figures 32.7 and 32.12 of Scoutt LM, Hamper UM, Angtuaco L, eds. *Ultrasound.* Oxford, UK: Oxford University Press; 2017.

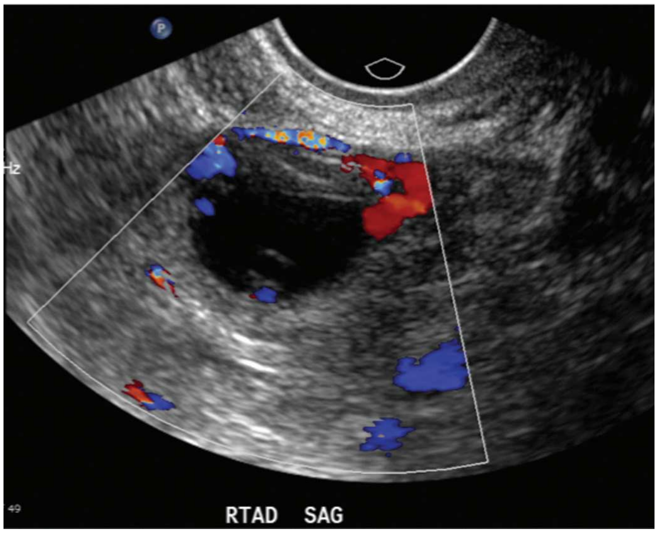

Figure 9.12

20. A 25-year-old female presents with vaginal spotting for the past 2 days. Her LMP started 8 weeks ago. She has mild suprapubic tenderness but otherwise appears well. Her pelvic exam is unremarkable except for trace vaginal bleeding and a closed cervical os. Her urine pregnancy test is positive. You perform a bedside transvaginal ultrasound and obtain the images in Figure 9.13 and Video 9.1.

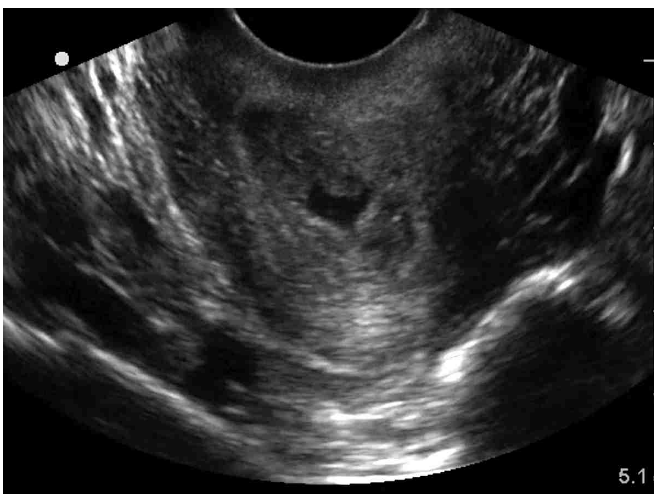

Figure 9.13

What is the likely diagnosis?

A. Intrauterine pregnancy
B. Ectopic pregnancy
C. Indeterminate pregnancy
D. Inevitable abortion

21. A 24-year-old G1P0 female presents supine in full spinal immobilization after a motor vehicle accident. She was a seat-belted front seat passenger in a vehicle that sustained 18 inches of passenger space intrusion. She is 30 weeks pregnant and has had regular prenatal care. Her vital signs are heart rate 120, blood pressure 85/60, respiratory rate 22, SpO_2 98% on room air. She has 2 peripheral IVs in place by emergency medical services. She is complaining of abdominal pain and has a positive seat belt sign. What is the next appropriate step in management?

A. Abdominal and pelvic CT scan
B. FAST examination
C. Emergent consult to OB
D. Reposition the patient, followed by the FAST examination

22. A 29-year-old female, G2P1 and Rh+, at 34 weeks EGA, presents to the ED after a low-speed motor vehicle accident. She was rear-ended by a car going approximately 10 MPH. Her only complaint is some lower abdominal cramping. She has been getting regular prenatal care for her pregnancy and has not had any complications. Her FAST examination is negative, and her vital signs are normal. Her abdominal exam shows a somewhat tender, gravid uterus with fundus several fingers above the umbilicus; there is no seat belt sign or other signs of trauma. On external examination there is no vaginal bleeding or obvious leakage of fluid. You perform a bedside transabdominal ultrasound which shows fetal movement and a fetal heart rate of 90 but is otherwise unremarkable. What is the next step in management?

A. Perform serial FAST examinations and discharge after brief observation
B. Give acetaminophen for pain and discharge with OB follow-up
C. Start external cardiotocography and consult OB
D. Obtain pelvic magnetic resonance imaging (MRI)

23. A 32-year-old G6P5 female presents to a small ED in active labor. She is 38 weeks EGA and has been getting prenatal care. Her vital signs are stable, and physical exam shows no crowning or visible fetal parts. You perform a transabdominal ultrasound, shown in Figure 9.14.

What is the next appropriate step in management?

A. Prepare for precipitous delivery of cephalic presenting fetus.
B. Consult OB for breech delivery.
C. Perform the McRoberts maneuver.
D. Consult OB for emergent cesarean section.

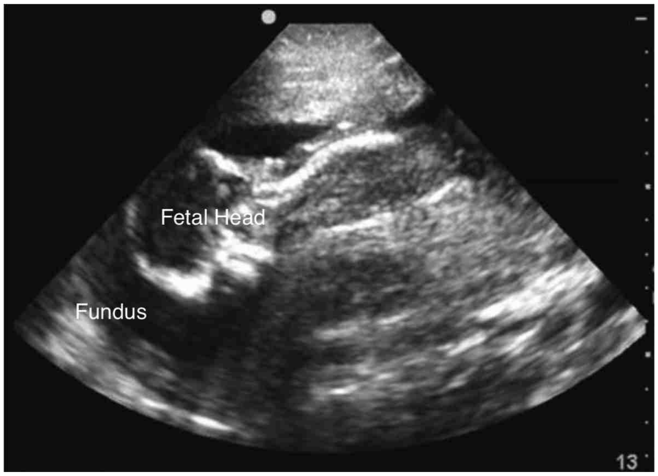

Figure 9.14 From Figure 16.16 of Gullet J, Pigott DC. Second and third trimester pregnancy. In: Cosby KS, Kendall JL, eds. *Practical Guide to Emergency Ultrasound*. 2nd ed. Philadelphia, PA: Lippincott, Williams and Wilkins; 2014:242.

24. A 29-year-old female, G2P1, presents with abdominal pain after falling off a stepladder at home. She believes she is about 26 pregnant but has not had any prenatal care since her initial ultrasound at 8 weeks. You perform a transabdominal bedside ultrasound and obtain the image in Figure 9.15.

Figure 9.15 **Amniotic fluid assessment with maximum vertical pocket (MVP) method.**

What can you say about the amount of amniotic fluid?

A. Oligohydramnios
B. Normal amount of amniotic fluid
C. Polyhydramnios
D. More images needed

25. A 26-year-old G3P2 female at 8 weeks EGA by last menstrual cycle presents with crampy lower abdominal pain. Her vital signs are stable. The pelvic exam is unremarkable and the cervical os is closed. You perform a transabdominal ultrasound and obtain the images in Figure 9.16.

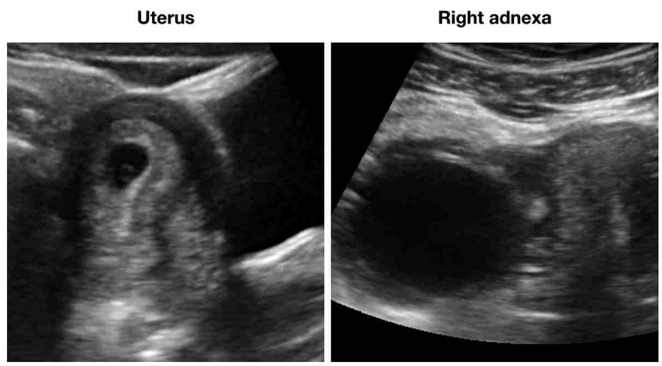

Figure 9.16

What is your diagnosis?

A. Normal IUP and corpus luteum
B. Heterotopic pregnancy
C. Ectopic pregnancy
D. Missed abortion

26. A 34-year-old G3P2 female at 36 weeks EGA presents for onset of contractions about 10 minutes apart. She has had 2 intermittent episodes of painless vaginal bleeding during her pregnancy, and she has had serial ultrasounds. However, she does not remember her medical condition. On exam, she is in no acute distress, her vital signs are within normal limits, and the fetal tocodynamometry is reassuring. You perform a transabdominal ultrasound exam, shown in Figure 9.17.

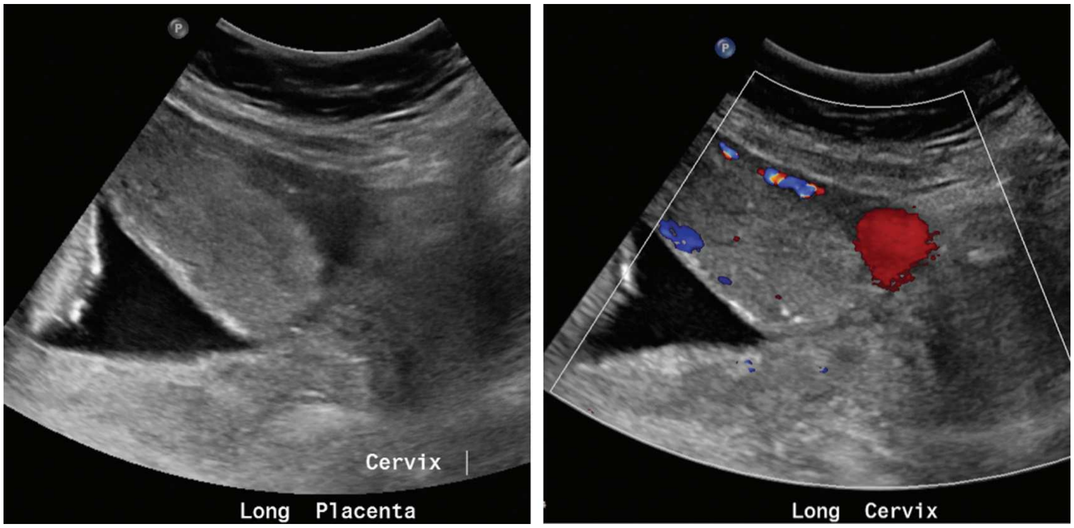

Figure 9.17 *Image courtesy of Shaden Mohammad, MD, Department of Radiology, Olive View–UCLA Medical Center, Los Angeles, CA.*

What is an appropriate step in management?

A. Avoid a bimanual exam
B. Large bore IV placement and type and crossmatch
C. Consult OB for emergent C-section
D. All of the above

ANSWERS

1. EXPLANATION

C. Curvilinear, OB, M-mode. The curvilinear probe or the endocavitary probe should be used for this application. The linear probe cannot visualize structures deeper than 9 cm, which is often inadequate for imaging of the pelvic structures. OB settings allow for lower sound energy to be transmitted to the developing fetus. Doppler mode should be avoided in the first trimester because of the higher thermal index (TI) and mechanical index (MI), which theoretically may heat or distort developing tissue. As an alternative to Doppler, the fetal heart rate can be quantitated using M-mode (Figure 9.18). While there is no evidence that a higher TI or MI results in worse outcomes, this principle is based on the "as low as reasonably achievable" (ALARA) principle.

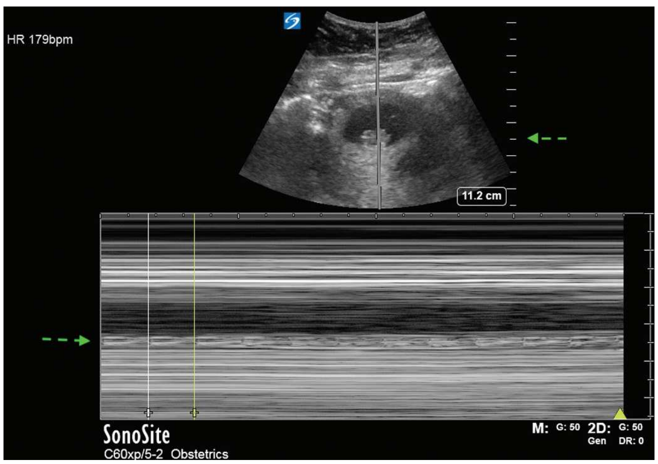

Figure 9.18 **Fetal heart rate assessment with M-mode.** The tracing line is placed over the fetal heart to generate the tracing below. The x-axis covers time over a four second period, with the duration adjustable. The y-axis corresponds to depth, so that the depth of the fetal heart in the 2D image (~7 cm) can be used to identify the motion of the heart at the same depth (arrows) on the M-mode tracing. Interval bars are then set to calculate a fetal heart rate.

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Keywords/Tags: OB, knobology, acquisition, fetal heart rate

> **Learning Point 1**: M-mode should be used to assess for fetal heart rate in the first trimester, using a curvilinear probe on obstetrics (OB) exam setting.

2. EXPLANATION

C. Curvilinear probe in the longitudinal axis with probe marker cephalic and transverse axis with probe marker to the patient's right. When performing transabdominal ultrasound, place the curvilinear probe on the abdomen, just above the pubic symphysis, in both longitudinal (sagittal) and transverse axes. In the sagittal plane, the probe marker should point cephalad. In the transverse plane, the probe marker should point to the patient's right [Figure 9.19]. Center the structures of interest on the screen and adjust the depth and gain to optimize the image.

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Keywords/Tags: OB, knobology

> **Learning Point 2:** A curvilinear transducer should be used for transabdominal obstetric ultrasound, with the indicator directed cephalad for a sagittal plane, and to the patient's right for a transverse plane.

3. EXPLANATION

B. Perform the transabdominal exam, allow the patient to use the bathroom, then perform the transvaginal exam. Performing the transabdominal exam with a full bladder has several advantages. A full bladder pushes the small bowel out of the way, displacing its gaseous contents and allowing better visualization of the more posterior structures, including the uterus and adnexa. A full bladder also provides a clearer sonographic window as sound waves travel well through liquid (urine). Finally, the bladder can be used as a sonographic landmark for identification of the uterus and adnexa [Figure 9.20].

For the transvaginal exam, the endocavitary probe is placed in the vagina and sound waves travel through the cervix and uterus. The bladder is anterior and so does not provide an acoustic window in the transvaginal exam. Rather, it can cause posterior acoustic enhancement artifact, which can distort the image. An empty bladder is also more comfortable for the patient.

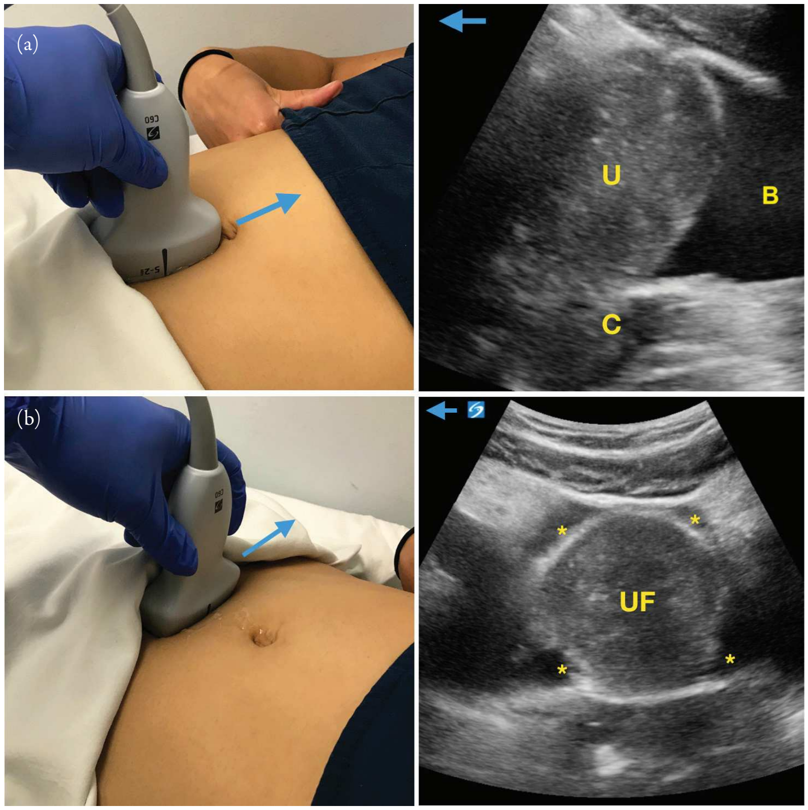

Figure 9.19 (a) **Placement of transducer in transabdominal pelvic exam in sagittal orientation.** Note that the indicator is pointed cephalad, so that the left side of the screen is oriented superiorly. The uterus (U) is seen in long axis on a sagittal plane, with the bladder just inferior (B), and the cervix (C) posterior. (b) **Placement of transducer in transabdominal pelvic exam in transverse orientation.** Note that the indicator is pointed to the patient's right, so that the left side of the screen is oriented to the patient's right as well. As the majority of uteri are anteverted, this gives more of a coronal view of the uterus, and in particular, the uterine fundus (UF). The bladder borders (*) the more inferior portions of the uterus.

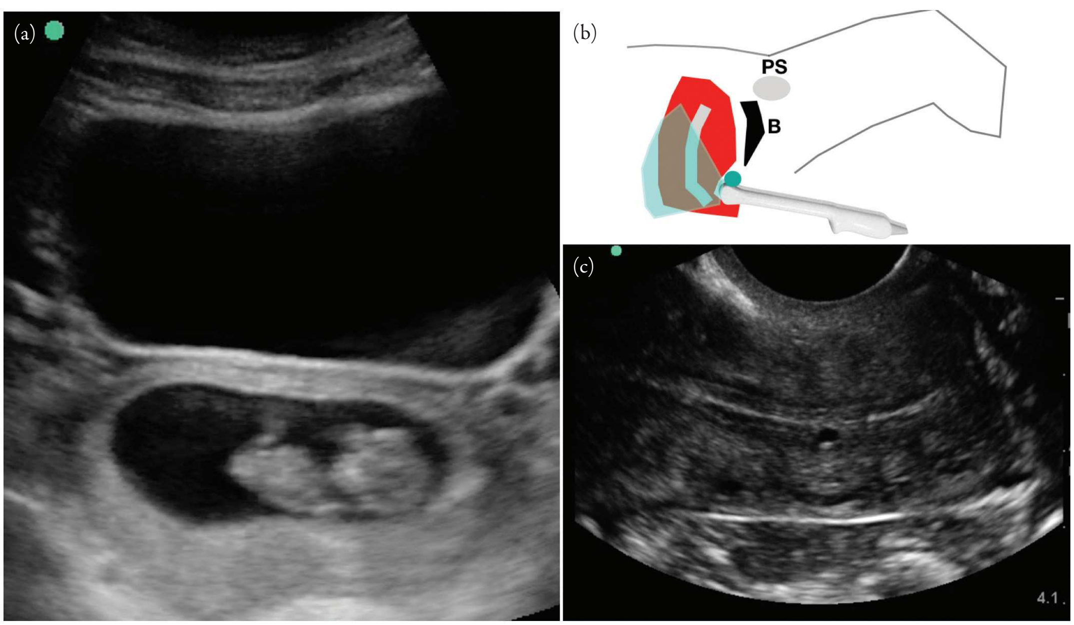

Figure 9.20 (a) **Transabdominal pelvic exam with full bladder.** This transverse view shows the importance of a full bladder in the transabdominal window. The ultrasound beam is able to pass through the fluid-filled bladder to image the intrauterine pregnancy just posterior to the bladder. With an empty bladder, air-filled bowel will surround the uterus, and shield it from ultrasound visualization. (b) **Transvaginal pelvic exam with empty bladder.** In the top panel, the decompressed bladder (B) lies just superior-posterior to the pubic symphysis (PS), allowing the uterine body and fundus to be closer to the transducer. The indicator is pointed anteriorly, so that the left of the screen is also directed anteriorly. Because of this orientation, the uterine body and endometrial stripe are imaged perpendicular to the ultrasound beams (bottom panel, c), allowing for better resolution.

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Keywords/Tags: OB, knobology, image acquisition

> **Learning Point 3:** Perform a transabdominal scan with a full bladder; perform a transvaginal exam with an empty bladder.

4. EXPLANATION

D. Sterilized probe, sterile and nonsterile gel, transducer cover, chaperone, post-exam high-level disinfection. You should always use a clean endocavitary probe that has been sanitized by a high-level disinfectant to reduce patient-to-patient disease transmission. Additionally, a chaperone should accompany the clinician for all transvaginal ultrasounds. Place nonsterile ultrasound gel on the probe and insert it into the sterile transducer cover, taking care to expel any bubbles. Place sterile lubricant on the outside of the probe cover. Ask the patient to empty her bladder and position herself in the lithotomy position. When the procedure is finished, be sure to sterilize the endocavitary probe in high-level disinfectant, in accordance with your facility's standards.

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Keywords/Tags: OB, knobology, high level disinfection

> **Learning Point 4:** Transvaginal ultrasound should be performed with sterile gel and a sterile cover. High-level disinfection should be performed after every use.

5. EXPLANATION

C. 6 weeks. The endocavitary probe is a high-frequency probe, which provides detailed images at shallow depths. Transvaginal ultrasound can identify small structures, such as a yolk sac or fetal pole, as early as 5 weeks. Transabdominal ultrasound is performed using the curvilinear probe, which is a low-frequency probe that can penetrate deeper but lacks detail. Consequently, transabdominal ultrasound cannot reliably confirm an IUP until about 6 weeks EGA [Figure 9.21].

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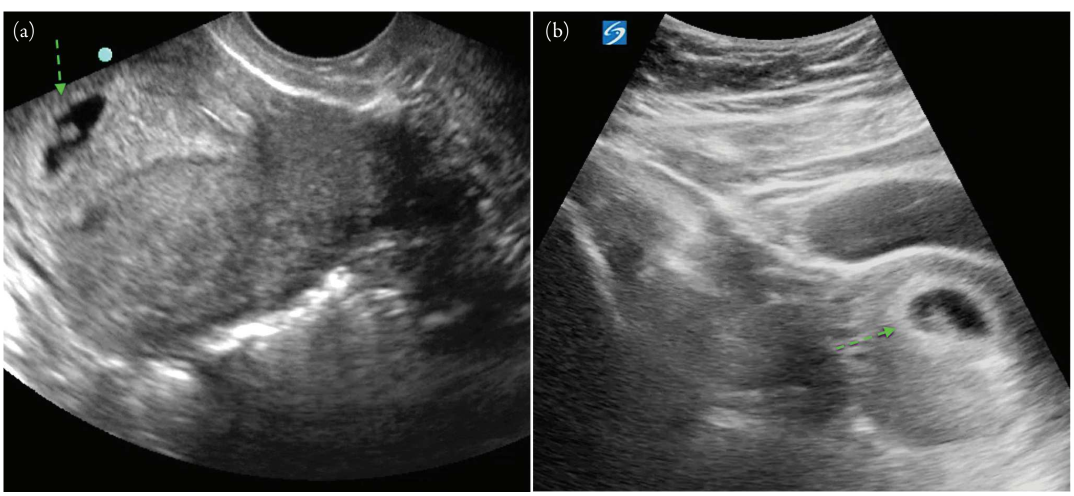

Figure 9.21 (a) Transvaginal ultrasound showing an intrauterine pregnancy (arrow). (b) Transabdominal ultrasound showing an intrauterine pregnancy (arrow).

Keywords/Tags: OB, knobology, image acquisitions

Learning Point 5: Transabdominal pelvic ultrasound can identify definitive IUP at approximately 6 weeks of gestational age, while transvaginal pelvic ultrasound can identify IUP at 5 weeks of gestational age.

6. EXPLANATION

D. All of the above. Up to 20% of women have a retroverted uterus, in which the fundus is pointed posteriorly versus the normal anterior position. On these transvaginal images of the uterus, note that the indicator dot points anteriorly in a sagittal plane. Therefore, (a) shows a retroverted uterus, while (b) shows an anteverted uterus.

In pregnancy, the vast majority of retroverted uteri will spontaneously move toward an anterior position with an increasingly gravid uterus. However, in about 1 in 3,000 pregnancies, the uterus maintains its retroverted position during the second and third trimesters. This leads to the gravid uterus becoming more wedged between the bladder and sacral structures. There is an association with increased risk of bladder outlet obstruction, uterine vessel insufficiency, and miscarriage, as well as bowel ischemia. Patients with gestational ages between 14 and 20 weeks may be referred to ObGyn for potential maneuvers performed under general anesthesia to correct uterine positioning.

Also, in nonpregnant patients, an anteverted uterus has an orientation that is essentially perpendicular to the vaginal long axis. Retroverted uteri, in contrast, have a long axis that is similar to the vagina. Therefore, there is about a four to five times association with uterine prolapse.

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Keywords/Tags: retroverted uterus

Learning Point 6: A retroverted uterus is associated with uterine prolapse in the nongravid female and bladder outlet obstruction as well as incarceration of the uterus during the second and third trimesters of pregnancy.

7. EXPLANATION

D. No, a gestational sac is not definitive evidence of an IUP. A thin walled sac within the uterus is not definitive evidence of an IUP. It may be a gestational sac or a decidual cyst or endometrial breakdown during an ectopic pregnancy (the pseudogestational sac). A gestational sac is not definitive evidence of an IUP. A yolk sac would appear as a separate ring-like structure inside the gestational sac and does confirm an early IUP. The yolk sac provides initial circulation from the mother to embryo before full development of placental circulation as well as the fetal heart. It is seen on transvaginal ultrasound at about 5 weeks. The embryo is seen at about 6 weeks as an oblong structure 1 to 2 mm in length. As such, it is referred to as the fetal pole. Visualization of a fetal pole also confirms early IUP (see Figure 9.22 and Video 9.2).

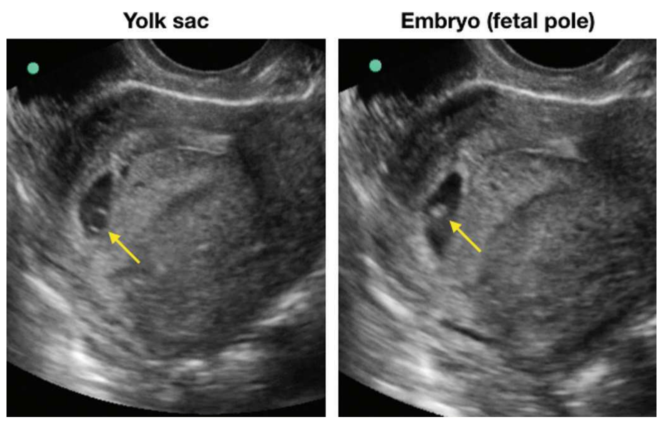

Figure 9.22 **Yolk sac and fetal pole on transvaginal ultrasound.**

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Keywords/Tags: gestational sac, yolk sac, fetal pole

Learning Point 7: A definitive IUP on ultrasound includes visualization of a gestational sac with either yolk sac and/or fetal pole.

8. EXPLANATION

C. IUD embedment. IUDs are a form of temporary contraception that are rapidly growing in popularity. The T-shaped copper IUD (ParaGard) and levonorgestrel-releasing IUDs

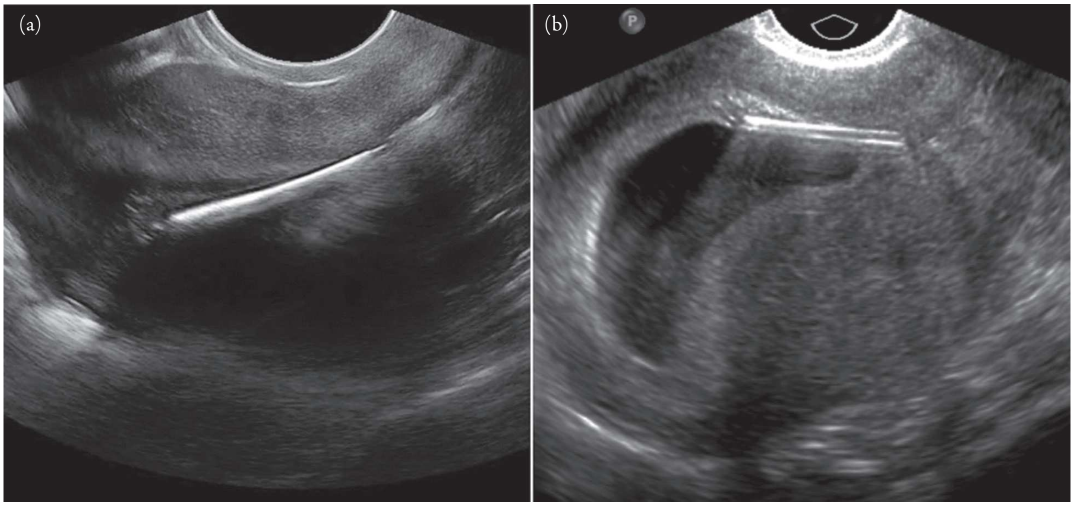

Figure 9.23 (a) **Correctly situated intrauterine device on transvaginal ultrasound.** Note that the axis of the IUD is inline with the endometrium. *Image courtesy of Dasia Esener, MD, Department of Emergency Medicine, Kaiser Permanente San Diego Medical Center, San Diego, CA.* (b) **Displaced IUD with intrauterine pregnancy (IUP) on transvaginal ultrasound.** This low-lying IUD is seen as an echogenic double-linear band with some ringdown artifact. The IUP is just deep and to the left or fundal to the IUD. Note that the IUD axis is not inline with the endometrium. *Image courtesy of Anokh Pahwa, MD, and Shaden Mohammad, MD, Department of Radiology, Olive View–UCLA Medical Center, Los Angeles, CA.*

(Mirena, Liletta, Skyla, and Kyleena) are the 2 categories of IUDs available in the United States. Normal placement of the IUD is in the uterine fundus with the arms extending laterally toward the cornua (see Figure 9.23a).

IUDs can migrate out of correct position, which may lead to a variety of complications, including ineffective contraception, vaginal bleeding, and pelvic pain.

The IUD displacement can occur in four different ways:

1. Expulsion: The IUD is passed completely or impartially through the external cervical os. This occurs typically in the first year after placement and in about 5% of patients.
2. Displacement: The IUD is rotated or inferiorly displaced into the lower uterine segment. Displaced copper IUDs are associated with a 6 times risk of pregnancy (see Figure 9.23b).
3. Embedment: The IUD is embedded into the myometrium without serosal involvement, typically at the time of IUD insertion. Figure 9.3 and Video 9.3 show the IUD embedded into the posterior myometrium.
4. Perforation: In about 1 in 1,000 insertions, an IUD can perforate the myometrium and serosa of the uterus, resulting in cramping and pain. In a large prospective study, breastfeeding at the time of insertion was association with a 6-fold increase in risk of subsequent perforation, as well as a 2-fold increase in risk of perforation if the IUD was implanted <36 weeks after delivery.

Placement can be determined using ultrasound and abdominal radiographs, as all types of IUDs are radiopaque. On ultrasound, signs of a malpositioned IUD include not located within the fundus, as well as the IUD axis not in line with the endometrial stripe.

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Keywords/Tags: intrauterine device, IUD displacement

Learning Point 8: Intrauterine devices (IUD) are placed in the uterine fundus with the arms extending into the cornua. IUD displacement occurs rarely but, when it occurs, it can be confirmed with radiography or point-of-care ultrasound (POCUS).

9. EXPLANATION

C. Normal pregnancy with physiologic free fluid. A small amount of free fluid within the pelvis in both pregnant and nonpregnant females can be normal. Because a gestational sac and fetal pole are seen in the uterine fundus in Figure 9.4, this is confirmation of an IUP. However, if an

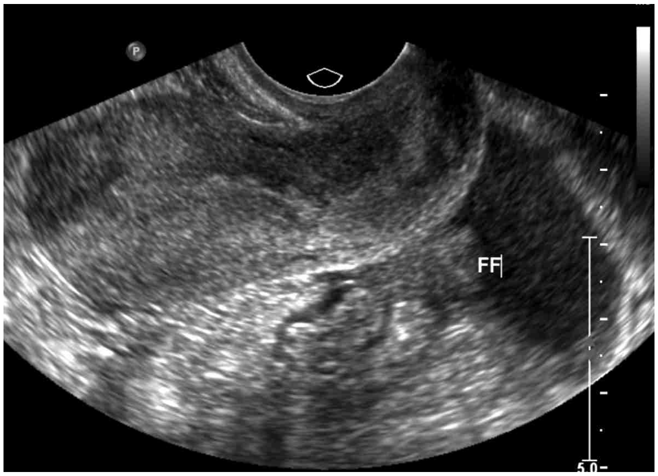

Figure 9.24 **Free fluid (FF) in the posterior cul-de-sac or rectouterine space, as seen on transvaginal ultrasound.** *Image courtesy of Monica Deshmukh, MD, Department of Radiology, Olive View–UCLA Medical Center, Los Angeles, CA.*

IUP had not been clearly identified, this ultrasound could be concerning for an ectopic. Additionally, small amounts of free fluid in the pelvis can be seen on ultrasound for appendicitis. Free fluid in the rectouterine space (aka pouch of Douglas) is best seen on transvaginal ultrasound (see Figure 9.24). While this is usually physiologic, fluid in the vesicouterine space should raise concerns for a pathological process.

In addition, the presence of free fluid may complicate the assessment of a pregnant trauma patient, as it could also represent hemoperitoneum. In a trauma patient, echogenic material within the free fluid are highly concerning for hemorrhage. Our patient has normal vital signs and no abdominal tenderness or history of trauma, so the other answer choices are unlikely.

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Keywords/Tags: rectouterine space, vesicouterine space, pouch of Douglas

Learning Point 9: A small amount of free fluid within the pelvis is normal and physiologic, especially within the rectouterine space (aka the pouch of Douglas).

10. EXPLANATION

D. Threatened abortion with normal fetal heart rate. Fetal cardiac activity can be detected at the very earliest between 5.5 to 6.5 weeks gestational age. In the earliest stages of development (crown rump length [CRL] <5 mm), the fetal heart rate (FHR) should be >80 BPM. Throughout the rest of pregnancy, normal FHR ranges from 100 to 180.

Low FHR can be a sign of fetal distress or impending fetal demise. On transvaginal ultrasound, embryos with a CRL >5 mm on transvaginal ultrasound, or >9 mm on transabdominal exam, should demonstrate a FHR >100 beats per minute. Bradycardia or lack of cardiac activity is concerning for fetal demise.

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Keywords/Tags: threatened abortion, crown rump length, fetal heart rate

Learning Point 10: Fetal heart rate can be measured at approximately 6 weeks gestation and should be between 110 and 180 beats per minute (BPM).

11. EXPLANATION

D. Ectopic pregnancy. This patient has an eccentrically implanted pregnancy that has <5 mm of myometrial thickness (red line), suggestive of interstitial pregnancy. Interstitial pregnancies are an uncommon type of ectopic pregnancy. They account for only 2% to 4% of all ectopic pregnancies or about 1/2,500 to 1/5,000 of pregnancies. However, they are associated with a 2 to 5 times increase in mortality compared to other tubal ectopic pregnancies. In interstitial ectopic pregnancies, the embryo implants in the proximal section of the fallopian tube just as it penetrates the myometrium but outside of the true uterine cavity. Rupture typically occurs in late first trimester or second trimester, as the enlarging embryo erodes into the arteries of Sampson, leading to hemorrhage.

The criteria for diagnosing an interstitial pregnancy are

1. An empty uterus.
2. An eccentric gestational sac located 1 cm from the most lateral uterine wall.
3. A thin myometrium less than 5 mm.
4. The “interstitial line sign”: an echogenic line that runs from the endometrial cavity to the periphery of the interstitial mass or gestational sac. This line is thought to represent the interstitial portion of the fallopian tube (see Figure 9.25).

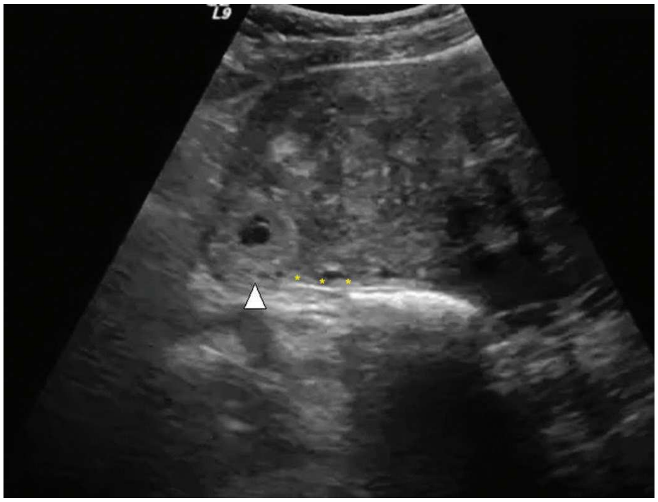

Figure 9.25 **Interstitial line sign.** On this transvaginal ultrasound, there is a gestational sac with yolk sac (arrowhead) that is eccentrically located with a thin rim (<5 mm) of surrounding myometrium. In addition, there is presence of an interstitial line sign (*). From Figure 27.4 of Attaya HN, Abujudeh HH. Obstetric first trimester emergencies. In: Abujudeh H, ed. *Emergency Radiology*. Oxford, UK: Oxford University Press; 2016.

These criteria together are only 80% sensitive but up to 98% specific.

Of note, interstitial pregnancies are *not* cornual pregnancies, which refer to pregnancies in the horn of a bicornuate uterus. Interstitial pregnancies are also often mistaken for angular pregnancies, which are viable IUPs that implant in the lateral angles of the uterine cavity, medial to the uterotubal junction.

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Keywords/Tags: interstitial ectopic pregnancy, myometrial mantle, interstitial line sign

Learning Point 11: Interstitial ectopic pregnancy is a rare type of ectopic pregnancy characterized by location in the interstitial fallopian tube, with a small surrounding myometrial layer (<5 mm), and interstitial line sign.

12. EXPLANATION

C. Perform a STAT transvaginal ultrasound. The concept of a discriminatory zone refers to the stage of pregnancy in which the gestational sac and either yolk sac or fetal pole should be visualized on ultrasound. For transvaginal ultrasound, the βHCG level should exceed 1500 to 3000 mIU/ml for adequate visualization. For transabdominal ultrasound, the βHCG should be greater than 5000 to 10,000 mIU/ml.

However, in ectopic pregnancies, the βHCG does not rise normally per the stage of development. Wang et al. showed that roughly two-thirds of patients with ectopic pregnancies who present to the ED have a βHCG < 3000 mIU/ml. Kohn et al. had a similar finding of women who presented with pelvic pain or vaginal bleeding, that a βHCG < 1500 mIU/ml doubled the likelihood of an ectopic pregnancy diagnosis.

In terms of POCUS accuracy, in a meta-analysis of emergency physician POCUS to evaluate for ectopic pregnancy, Stein et al. found a sensitivity of 99.3% (95% confidence interval [CI], 96.6% to 100%) and negative predictive value of 99.96% (95% CI 99.6% to 100%).

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Keywords/Tags: OB, ectopic pregnancy, beta HCG

Learning Point 12: When ectopic pregnancy is suspected, the typical cut-offs of the discriminatory zone for beta (β) hCG levels should not be applied. Ectopic pregnancies typically have lower quantitative human chorionic gonadotropin (hCGs) than normal pregnancies.

13. EXPLANATION

C. Biparietal diameter of 6.5 cm. Perimortem caesarian section is a rare procedure that is potentially lifesaving for both the mother and fetus. Releasing compression of the inferior vena cava and increasing venous return to the heart can improve maternal hemodynamics during CPR. However, given the risks of the procedure, and the time and resources involved, it should only be undertaken if the fetus

is of a viable gestational age, which by current consensus is 24 weeks. In a review of the limited literature on this topic by Katz et al., there was a 90% infant survival rate and a 66% maternal survival rate with perimortem C-section. Therefore, when the EGA is unknown, and fundal height is in the proximity of the umbilicus, transabdominal POCUS may be performed to improve estimation.

CRL is used to estimate gestational age during the first trimester after the development of the fetal pole. It is performed by measuring from the tip of the cephalic pole to the tip of the caudal pole. A fetus at 13 weeks will measure approximately 7 cm. After the first trimester, the fetus becomes significantly flexed and curved, and this measurement is less accurate (see Figure 9.26a).

Cardiac activity alone is insufficient to determine the need for perimortem c-section.

Biparietal diameter (BPD) can be used from 12 weeks until the end of pregnancy to date a fetus, though it becomes less accurate at later gestational ages. Tunon et al. showed that BPD is accurate within 2 days in 208 singleton pregnancies via in vitro fertilization, where the gestational age is known. In a review of over 17,000 singleton pregnancies, Nguyen et al. found the BPD deviated from a reliable LMP by 1 day. To measure BPD, image the skull in a transverse plane, with both thalami visualized. Measure from *outer* edge of one parietal bone to the *inner* edge of the contralateral parietal skull. BPD >6 cm roughly corresponds to gestational age at or greater than 24 weeks (Figure 9.26b).

Femur length can be used from 14 weeks until term to accurately date pregnancy and has roughly the same accuracy as BPD (Figure 9.26c). Find a femur and measure the bone end to end in long axis (disregarding curvature). Femur length of approximately 4 to 4.5 cm roughly corresponds to a gestational age greater than 24 weeks. While combined measurements of BPD and femur length increase accuracy of dating, often the femur length is more difficult to perform, especially in a time-sensitive situation like maternal cardiac arrest.

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Keywords/Tags: OB, biparietal diameter, femur length, peri-mortem c-section

Learning Point 13: Peri-mortem c-section should be performed if the fetus is viable (>24 weeks EGA). Transabdominal POCUS can estimate EGA, with a BPD > 6cm or femur length > 4 cm corresponding to EGA > 24 weeks.

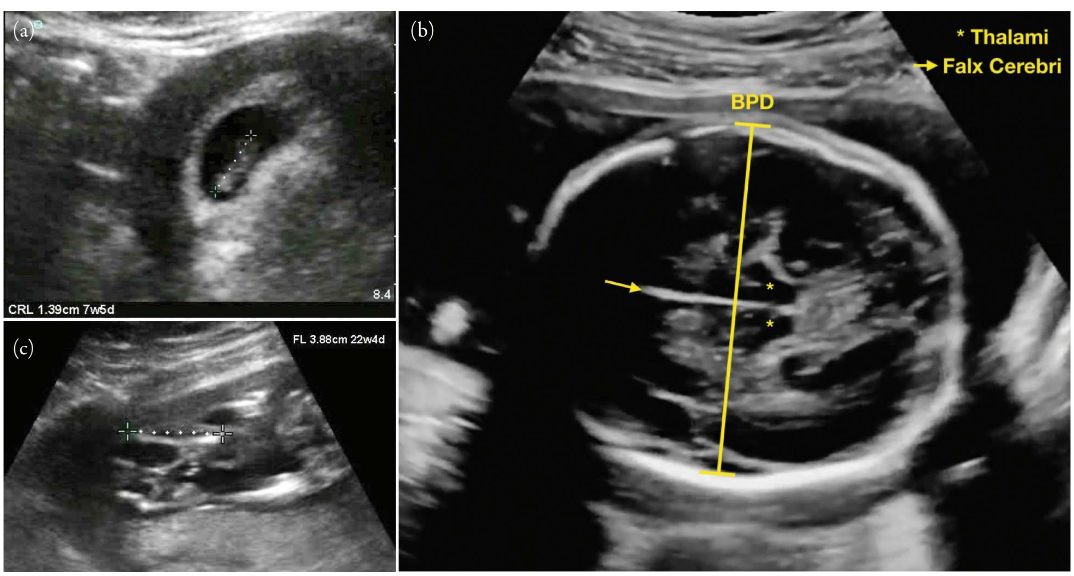

Figure 9.26 (a) Crown rump length method for estimating gestational age in first trimester. (b) Biparietal diameter method (BPD) for estimating gestational age in second and third trimesters. Note that the thalami (*) and falx cerebri (arrow) should be visualized in this plane, and the BPD should be measured from outer parietal bone to inner parietal bone. (c) Femur length method for estimating gestational age in second and third trimesters.

14. EXPLANATION

D. Molar pregnancy. Molar pregnancy complicates approximately 1 in 1,000 pregnancies in the United States. Gestational trophoblastic disease is a spectrum ranging from partial mole, to complete mole, to local placental trophoblastic tumor, to metastatic invasive trophoblastic disease. Symptoms tend to be exaggerations of pregnancy-related symptoms, including hyperemesis gravidarum and anemia, as well as hyperthyroidism. In addition, upon exam, the fundal height may be higher than what is expected for EGA.

In partial molar pregnancy, 2 sperm fertilize 1 egg, resulting in the presence of some fetal parts (occasionally manifested as cardiac activity with fetal size small for gestational age), a large uterus and placenta, and hypertrophic villi (see Figure 9.27). This can be a difficult diagnosis to make on ultrasound and is frequently not identified until tissue pathology after histologic evaluation.

Complete molar pregnancies result from 2 sperm fertilizing an empty ovum. Placental villi change into molar vesicles, which appear as a "cluster of grapes" or "snowstorm" on ultrasound (Figure 9.7). Both have the potential to develop into invasive trophoblastic disease, but the rates are much higher with complete molar pregnancies. Common sites of metastases are the lung (which this patient likely has, given her chest X-ray), brain, liver, and spleen. Treatment is removal of the molar tissue and chemotherapy.

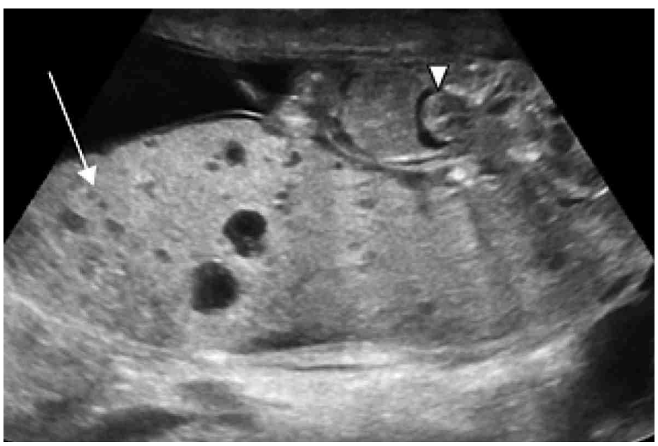

Figure 9.27 **Partial molar pregnancy on transvaginal ultrasound.** Note the presence of molar vesicles in the placenta (arrow) as well as fetal parts (arrow head). From Figure 35.1 of Scoutt LM, Hamper UM, Angtuaco L, eds. *Ultrasound*. Oxford, UK: Oxford University Press; 2017.

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Keywords/Tags: molar pregnancy, cluster of grapes, trophoblastic disease

Learning Point 14: Complete molar pregnancies are seen as a "cluster of grapes" on POCUS, whereas incomplete molar pregnancies may be visualized as heteroechoic densities that represent fetal tissue.

15. EXPLANATION

A. Consult OB for postpartum endometritis and start intravenous (IV) antibiotics. This patient is suffering from endometritis in the setting of prolonged rupture of membranes. She is tachycardic and borderline febrile, with suprapubic tenderness. On POCUS, the patient has an abnormally thickened endometrial stripe, suggestive of inflammation and infection. Abnormal endometrial stripes may be thickened (>1 cm in postpartum period) or their contours may appear disrupted compared to the otherwise smooth endometrial stripe. In addition, the POCUS shows heteroechoic material (arrow) consistent with retained products of conception (RPOC), which may or may not demonstrate vascular flow on Doppler.

The rate of endometritis is 5 to 10 times greater in patients undergoing cesarean section than vaginal delivery. Risk factors for endometritis include prolonged rupture of membranes, chorioamnionitis, Group B streptococcus infection, bacterial vaginosis, manual placental removal, prolonged operative time, and multiple exams.

The patient should be admitted for IV antibiotics and potentially dilation and curettage of the RPOC.

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Keywords/Tags: retained products of conception, endometritis

Learning Point 15: Following a normal pregnancy and delivery, transabdominal ultrasound may be used to determine the presence of RPOC or a potential septic abortion. Findings include a thickened endometrium and echogenic material.

16. EXPLANATION

C. Consult OB for ectopic pregnancy. This patient has a cervical ectopic pregnancy, not an IUP. Cervical ectopic pregnancies occur in 1 in 9,000 pregnancies and are associated with assisted reproduction as well as a history of prior dilation and curettage. Early diagnosis is associated with nonsurgical interventions, such as the use of methotrexate. The diagnosis on transvaginal ultrasound should show an empty endometrial cavity with a gestational sac and fetal pole or yolk sac in the cervical canal.

Most ectopic pregnancies are found in the fallopian tubes (95%). Aside from tubal pregnancies, other locations of ectopic pregnancies include cervical, cesarean scar, interstitial, ovarian, or abdominal. Risk factors for ectopic pregnancy include prior ectopic pregnancy, pelvic inflammatory disease, IUD, smoking, and prior tubal ligation. Cervical ectopic pregnancies are at a particularly high risk of hemorrhage.

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Keywords/Tags: cervical ectopic pregnancy

Learning Point 16: Ectopic pregnancies can occur in a wide range of places: peritoneal cavity, ovaries, fallopian tubes, cervix, scars from prior uterine surgery, or the cornum of a bicornuate uterus. The most common locations for an ectopic is in the fallopian tubes (95%).

17. EXPLANATION

D. STAT consult OB for heterotopic pregnancy. This patient's bedside ultrasound shows both an IUP (a, arrow) as well as an ectopic pregnancy (b, arrow). Note the corpus luteal cyst (bold arrow, b) as well as the many ovarian cysts as a result ovulatory induction in IVF. This is consistent with the diagnosis of heterotopic pregnancy.

The risk of spontaneous heterotopic pregnancy is approximately 1/30,000 in patients not undergoing assisted reproductive techniques. However 1 in 100 to 300 of patients undergoing IVF are at risk for heterotopic pregnancy.

Note also that there is surrounding free fluid in the adnexa, which, along with the patient's presentation, is concerning for ruptured ectopic. While A and C may be part of the workup, emergent OB consultation should be the next step in management.

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Keywords/Tags: heterotopic pregnancy

Learning Point 17: Heterotopic pregnancy, the presence of a simultaneous ectopic pregnancy and an IUP, occurs in 1/30,000 spontaneous pregnancies and approximately 1/1,000 pregnancies that are the result of fertility treatment.

18. EXPLANATION

A. Consult ObGyn for an emergent laparotomy. The presence of free fluid in the right upper quadrant in the setting of a positive pregnancy test is highly suggestive of a ruptured ectopic pregnancy requiring surgical intervention. The transvaginal and transabdominal pelvic ultrasound has less diagnostic utility than the right upper quadrant ultrasound for determination of need for operative intervention. If the FAST scan is negative for fluid in the right upper quadrant or other free fluid, and the patient is appropriately resuscitated, then other tests including hCG levels and pelvic ultrasound would be appropriate. Of note, if the urine pregnant test had been negative, the other likely diagnosis for her presentation would be a ruptured hemorrhagic ovarian cyst leading to hemoperitoneum, which also would likely require operative intervention.

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Keywords/Tags: ruptured ectopic pregnancy, hemoperitoneum

Learning Point 18: Performing a FAST exam with your focused transabdominal ultrasound will allow for the assessment of free fluid associated with a possible ectopic pregnancy. Morrison's pouch is the first and most important place to look for free fluid.

19. EXPLANATION

B. The ring of fire sign. This ultrasound is suggestive of a tubal ectopic pregnancy. Definitive diagnosis of an ectopic tubal pregnancy includes a tubal mass with a yolk sac or embryo. Findings that are highly suggestive for ectopic pregnancy include a tubal ring and or an adnexal mass. A tubal ring is a hypoechoic circular structure with an echogenic outer structure. Doppler is used to identify vascular flow around a tubal ring has been referred to as the "ring of fire" sign. Other structures that may also display this same sign are corpus luteum cysts, so pressure can be applied to the fallopian tube with a bimanual exam to see if there is separation of the ectopic pregnancy from the ovary.

A cheerio sign is used to describe findings of a confirmed IUP: a gestational sac and a yolk sac. The target sign is ubiquitous in ultrasound, used for vascular access and many gastrointestinal tract pathologies. The Mickey Mouse sign is commonly used in right upper quadrant ultrasound and is composed of the portal vein (head), common bile duct (right ear), and hepatic artery (left ear), as well as deep vein thrombosis ultrasound for the common femoral vein and superficial and deep femoral arteries.

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Keywords/Tags: cheerio sign, rign of fire sign, tubal ectopic pregnancy

Learning Point 19: A tubal ring is an anechoic sac surrounded by a thick, echogenic wall clearly separated from the ovary. It is highly suggestive of a tubal ectopic pregnancy. The sonographer can apply pressure to the fallopian tube with the transducer to look for separation of the ovary and tubal ring.

20. EXPLANATION

C. Indeterminate pregnancy. The patient has nonspecific intrauterine fluid, which is often referred to as a pseudogestational sac. This term has fallen out of favor, as there is a false association with ectopic pregnancy, when only about 10% to 20% are associated with ectopic pregnancy. This has led to cases in which patients are treated for ectopic pregnancy, when in fact it may be an early pregnancy. In addition, patients with spontaneous abortion may also have a similar appearance in their endometrial cavity. Therefore, patients should have close follow-up for repeat βhCG levels and transvaginal ultrasound to confirm the diagnosis. Definitive pregnancy can be diagnosed with the presence of a yolk sac or fetal pole.

Two ultrasound findings that can support the presence of an early IUP are the intradecidual sign and the double decidual sign. The intradecidual sign is generally seen between 3 and 4 weeks by transvaginal ultrasound (Figure 9.28a). It is defined as an intrauterine fluid collection in a markedly thickened decidua on one side of the uterine cavity. The double decidual sign is when 2 echogenic rings surround the anechoic intrauterine fluid collection, formed by the decidua parietalis (lining the uterine cavity) and the decidua capsularis (lining the gestational sac). The double decidual sac sign appears after the gestational sac but before the yolk sac or fetal pole (Figure 9.28b). While the presence of these signs will increase the likelihood of an IUP (specificity 90%–100%), they are not present in many IUPs, with sensitivities in the 25% to 60% range. Therefore, the absence of these signs should not be construed as no IUP.

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Yeh HC, Goodman JD, Carr L, Rabinowitz JG. Intradecidual sign: a US criterion of early intrauterine pregnancy. Radiology. 1986;161(2):463–467.

Keywords/Tags: indeterminate pregnancy, intradecidual sign, double decidual sign

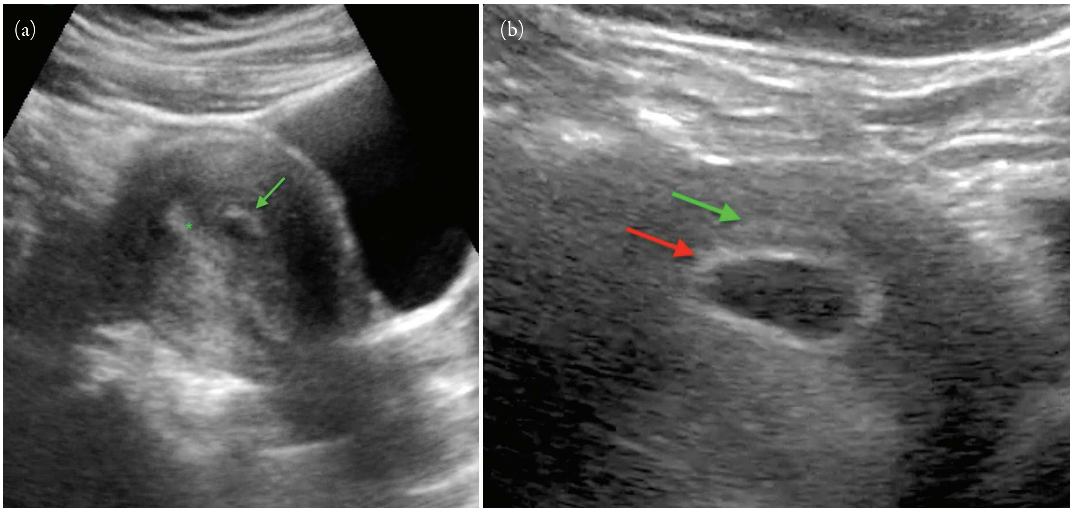

Figure 9.28 (a) **Intradecidual sac sign.** Note the anechoic sac is surrounded by an echogenic rim (due to the decidual reaction) and it is just anterior to the uterine cavity. (b) **Double decidual sac sign.** Note the two echogenic rings surrounding the gestational sac. The inner ring is the decidua capsularis (red arrow), while the outer ring is the decidua parietalis (green arrow).

Learning Point 20: Nonspecific intrauterine fluid collections may be found in both ectopic pregnancy as well as early pregnancy. Follow-up ultrasound and quantitative βhCGs should be performed to confirm either diagnosis.

21. EXPLANATION

D. Reposition the patient, followed by the FAST examination. The first step of stabilizing the pregnant trauma patient after quickly assessing her ABCs is to reposition the patient to the left lateral decubitus position to prevent aortocaval compression syndrome. This position will shift the gravid uterus to the left and release compression of the inferior vena cava. This will increase venous return and improve her hemodynamic status. Alternatively, a member of the resuscitation team can apply gentle pressure to the gravid uterus leftward to accomplish the same effect. The FAST examination should still be performed after these maneuvers. If the patient requires in-line stabilization, the patient can remain on the backboard and the whole board can be log rolled about 15 degrees to the left.

In trauma presentations, resuscitation of the mother is the primary objective, as the fetus depends on maternal circulation, and any episodes of maternal hypotension directly affect the fetus. Therefore, CT should be performed if indicated but not prior to initial stabilization. The same applies to emergent OB consult for fetal monitoring.

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Keywords/Tags: trauma in pregnancy

Learning Point 21: FAST exam in a pregnant patient should be performed in the left lateral decubitus position or with the gravid uterus repositioned slightly leftward.

22. EXPLANATION

C. Start external cardiotocography and consult OB. Severe placental abruption occurs in 1 in 800 to 1,600 pregnancies. It can be idiopathic, associated with advanced maternal age, diabetes, hypertension, as well as cocaine use. Placental abruption can also occur in pregnant trauma patients with a low energy mechanism. Placental abruption refers to retroplacental bleeding; however, hemorrhage can be subchorionic as well as subamniotic (see Figure 9.29). The risk of fetal demise is associated with the amount of placenta involved, from essentially 0% in subamniotic hemorrhage to 7% in subchorionic hemorrhage and 50% in placental abruption (see Figures 9.30 and 9.31).

Diagnosis can be difficult clinically, and ultrasound has had reported sensitivity of 50% due to the variable appearance of blood, which can appear similar to amniotic fluid or placenta itself. Color Doppler can be helpful to detect absence of flow to a suspected hematoma, with specificity as high as 90%.

Clinical judgement and high index of suspicion are crucial. Clinical signs and symptoms include vaginal bleeding, uterine tenderness, and contractions. Patients

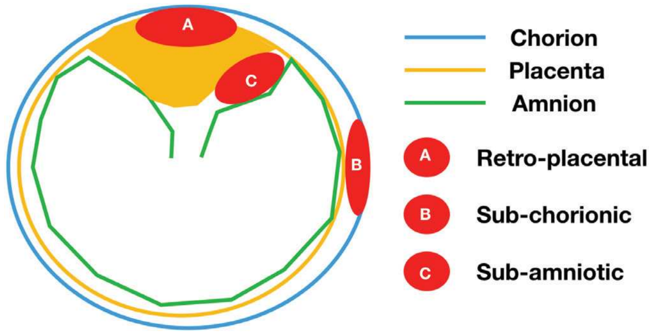

Figure 9.29 **Classification of hematomas involving placenta.** In class A, bleeding occurs behind the placenta, leading to potential placental insufficiency to the fetus. In class B, subchorionic hemorrhage is bleeding between the endometrium and chorionic layer, but can also extend behind the placenta. In class C, bleeding is between the placenta or chorionic layer and the amniotic layer. From Figure 1 of Trop I, Levine D. Hemorrhage during pregnancy: sonography and MR imaging. *AJR Am J Roentgenol.* 2001;176:607–615.

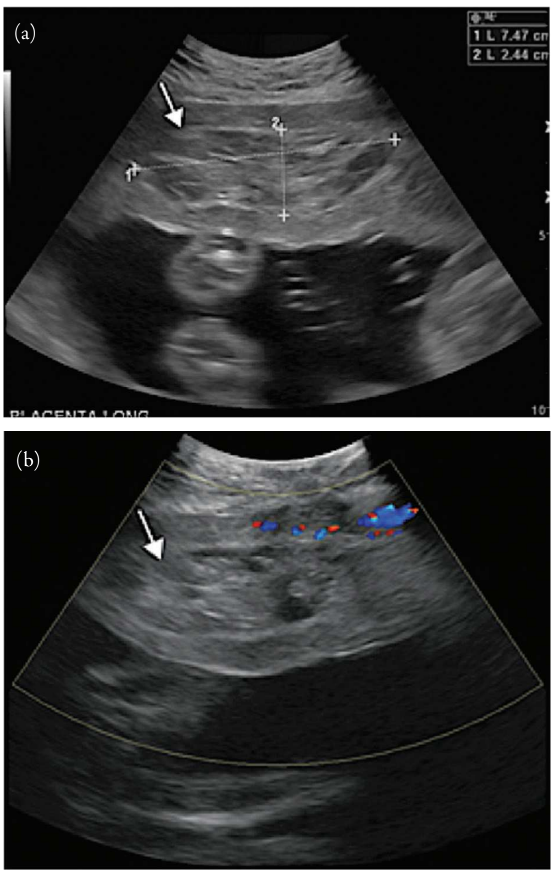

Figure 9.30 **Placental abruption**. In Panel (a) the (arrow) hematoma is between the placenta and myometrium, and appears heterogeneous. In Panel (b), the color Doppler is used to confirm the absence of flow to the hematoma (arrow). From Figures 40.5 and 40.6 of Scoutt LM, Hamper UM, Angtuaco L, eds. *Ultrasound.* Oxford, UK: Oxford University Press; 2017.

should undergo cardiotocographic monitoring for a minimum of 4 hours to evaluate for uterine irritability. In this case, the fetal heart rate of 90 is low and concerning for fetal distress. Maternal vital signs are often stable,

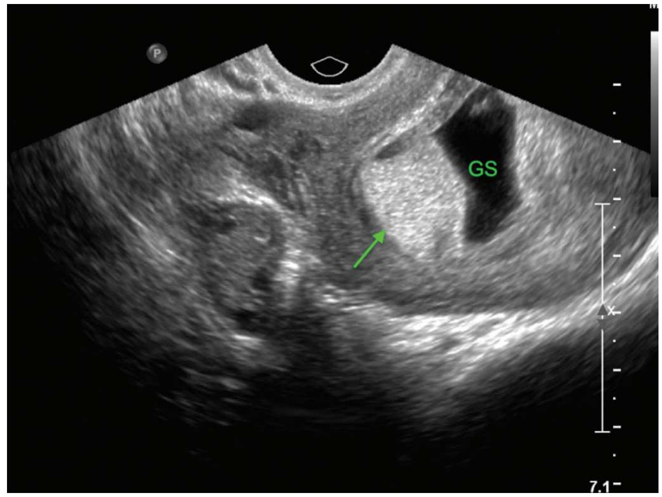

Figure 9.31 **Subchorionic hemorrhage.** This transvaginal ultrasound shows an acute, moderate size subchorionic hemorrhage (arrow) in this first trimester pregnancy. Acute hemorrhages will be hyperechoic, with decreasing echotexture with time. Size is graded by the extent of chorionic sac circumference involved: small (<1/3), medium (1/3–1/2), and large (>1/2). Large subchorionic hemorrhages are associated with a 20% risk of spontaneous abortion, while small subchorionic hemorrhage have an 8% rate. GS = gestational sac. *Image courtesy of Monica Deshmukh, MD, and Shaden Mohammad, MD, Department of Radiology, Olive View–UCLA Medical Center, Los Angeles, CA.*

and fetal distress may be the earliest clue to placental abruption.

Given the concern for fetal distress in this case, emergent OB consult is most appropriate. Of note, if there is uncertainty about the gestational age and viability, a biparietal diameter and/or femur length measurement can be performed. Serial FAST examinations may help to identify intra-abdominal injury but are not reliable for identifying placental abruption. It is inappropriate to discharge any trauma patient with a potentially viable pregnancy without a period of observation and cardiotocographic monitoring. MRI can be used to diagnose abruption; however, it is time intensive and not available at all institutions.

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Keywords/Tags: placental abruption

Learning Point 22: POCUS has low sensitivity for detecting placental abruption or blood between the placenta and uterus and should not be used to rule out this condition.

23. EXPLANATION

B. Consult OB for a breech delivery. Emergency physicians are often involved in precipitous deliveries. If time allows, POCUS can help to quickly determine EGA, multiparous gestation number of fetuses, and the presenting position (cephalic vs. breech). With the indicator pointed cephalad, this image shows a single fetus in breech presentation. In addition, if the maternal bladder is identified, it can be used as reference point.

Given the patient's multiparous status and risk for precipitous delivery, OB should be emergently consulted to help with an anticipated difficult delivery. Not all breech presentations require cesarean section, but this may be necessary if complications arise. Other helpful information can be gleaned from the POCUS exam. Kok et al. found that POCUS-derived predictors of successful external cephalic version include a complete breech (i.e., buttocks are most inferior part of the presentation, with legs flexed superiorly), posterior placenta, and amniotic fluid index (AFI) >10.

The ultrasound does not show a cephalic presenting fetus, which is the typical head down presentation for delivery (Figure 9.32). The McRoberts maneuver is used to aid delivery in the case of shoulder dystocia and is not warranted at this time.

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Keywords/Tags: breech delivery

Learning Point 23: Identify the presenting position of a third trimester fetus (breach, cephalic, etc.).

24. EXPLANATION

B. Normal amount of amniotic fluid. It is important to assess the amount of amniotic fluid because oligohydramnios (too little fluid) and polyhydramnios (too much fluid) are both associated with increased risk of perinatal mortality. If preterm labor is a concern, oligohydramnios may suggest premature ruptured of membranes.

We can assess the amount of fluid by measuring either the maximal vertical pocket (MVP) or amniotic fluid index (AFI). MVP (also known as single deepest pocket [SDP]) is easier to perform as only one measurement is required, versus four measurements for AFI. To obtain the MVP measurement, orient the probe cephalad and sweep the uterine cavity. Look for the deepest fluid pocket, free from umbilical cord or fetal parts. Freeze the image over the largest pocket and use calipers to measure the maximal depth. Normal MVP is 2 to 8 cm. The MVP in this image is 4 cm, consistent with normal amniotic fluid volume. Figure 9.33 shows a MVP of 2 cm, which is at the cut-off for oligohydramnios.

Figure 9.32 **Vertex (cephalic) presentation.**

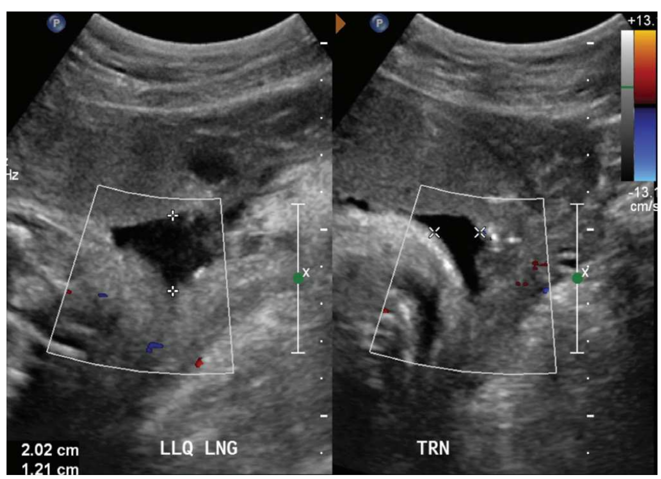

Figure 9.33 **Oligohydramnios with maximum vertical pocket of 2 cm.** *Image courtesy of Shaden Mohammad, MD, Department of Radiology, Olive View–UCLA Medical Center, Los Angeles, CA.*

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Keywords/Tags: amniotic fluid index, maximal vertical pocket, oligohydramnios

Learning Point 24: Amniotic fluid volume can be measured to obtain the maximum vertical pocket (MVP). If this measurement is <2 cm, it is consistent with oligohydramnios; if >8 cm, it is consistent with polyhydramnios.

25. EXPLANATION

A. Normal IUP and corpus luteum. This ultrasound image shows a normal first trimester pregnancy, with a gestation sac containing a yolk sac and surrounded by decidual reaction. The cystic structure in the adnexa is a corpus luteum. The corpus luteum forms in the ovary after ovulation. When fertilization occurs, the corpus luteum begins secreting progesterone and continues for approximately 10 weeks, when the placenta takes over. Corpus luteum is differentiated from an ectopic pregnancy because it is in the ovary, is surrounded by normal ovarian tissue, moves with the ovary with manipulation, and typically does not have a thick echogenic ring. In this case, the presence of an IUP also makes ectopic pregnancy unlikely.

Heterotopic pregnancy occurs when there is both an IUP and an ectopic pregnancy. This is extremely rare in the general population but should be considered in women undergoing fertility treatment.

A missed abortion would be seen as an empty gestational sac, also known as a "blighted ovum." This is due to stunted or no development of the embryo after conception. To make this diagnosis, the mean sac diameter (MSD) should be calculated by measuring inner wall to inner wall measurements of the sac in 3 orthogonal planes and dividing the total by 3. A MSD >25 mm is definitive for missed abortion (Figure 9.34). Of note, early molar pregnancies may appear similarly, so referral to OB is warranted for follow-up βhCG levels and ultrasound.

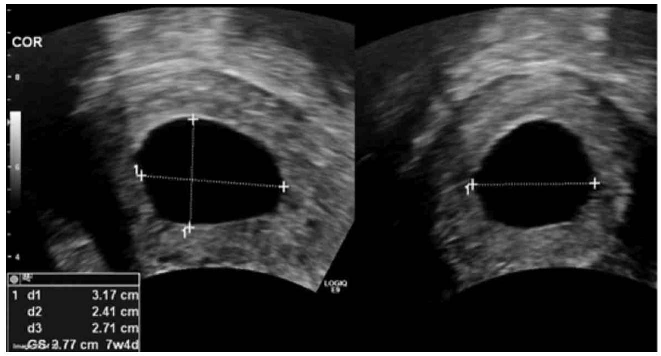

Figure 9.34 **Empty gestation sac.** Note that a mean sac diameter is calculated from three planes of the sac, and divided by 3. A mean sac diameter >25 mm without evidence of fetal pole or yolk sac is definitive for failed pregnancy. From Figure 26.3 of Scoutt LM, Hamper UM, Angtuaco L, eds. *Ultrasound*. Oxford, UK: Oxford University Press; 2017.

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Keywords/Tags: mean sac diameter, blighted ovum, corpus luteum

Learning Point 25: Corpus luteum is differentiated from an ectopic pregnancy because it is in the ovary, is surrounded by normal ovarian tissue, moves with the ovary with manipulation, and typically does not have a thick echogenic ring.

26. EXPLANATION

D. All of the above. The patient has evidence or placenta previa on the transabdominal ultrasound, with the placenta implanted within 2 cm of the internal cervical os. One in 200 pregnancies are complicated by placenta previa. Patients with placenta previa classically present with intermittent painless vaginal bleeding, with initial episode occurring in the third trimester in most patients (60%). This is due to development of the lower uterine segment during the third trimester, which is inefficient at contractions, and therefore stopping any bleeding. Partial placental

previa refers to only a portion of the cervix being obscured by the placenta, while complete or total previa involves the entire placenta covering the internal cervical os. Unless a report from a late third trimester (35–36 weeks) ultrasound is available, it is difficult to ascertain with POCUS complete versus partial previa.

Patients with placenta previa (particularly complete previa) are at high risk for significant hemorrhage and poor perinatal outcomes when they undergo vaginal delivery. Core tenets of management include:

1. Avoiding any digital cervical manipulation.
2. Preparations for massive hemorrhage, including type and crossmatch and large bore IV access.
3. Preparations for emergent C-section.
4. Tocodynamometry to assess for fetal distress.
5. Tocolysis if EGA is less than 37 weeks to administer corticosteroids for fetal lung maturation.

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Keywords/Tags: Placenta previa

Learning Point 26: Placenta previa is visualized as the placenta implanted within 2 cm of the cervix on ultrasound. Patients are at high risk for massive hemorrhage via vaginal delivery and should undergo C-section.

10.

GYNECOLOGICAL ULTRASOUND

Dasia Esener and M. Bryan Dalla Betta

QUESTIONS

1. A 26-year-old female presents to the emergency department (ED) with mild intermittent abdominal cramping in the lower quadrants. The patient is pain free now, and there was no trauma. She has no pertinent medical history and her last menstrual period (LMP) was 3 weeks ago. On physical exam, no fluid is seen in the vaginal vault; there is a normal cervix and mild uterine tenderness. She has a negative serum human chorionic gonadotropin (hCG). As part of the evaluation, a bedside transvaginal ultrasound is obtained, shown in Figure 10.1.

Figure 10.1

Which is true regarding the finding in the image?

A. Can be normal dependent on the patient's menstrual cycle
B. Is only normal in early pregnancy before the fetus is visualized
C. Only occurs with hemorrhagic ovarian cysts
D. Always abnormal

2. A 24-year-old female G0, P0 presents for evaluation of amenorrhea. She states that she has not had her period in 7 weeks, is sexually active, and has had intermittent vaginal bleeding since this morning. Urine hCG is positive and you plan to perform an ultrasound to assess for ectopic pregnancy after pelvic exam. When performing pelvic ultrasound, pelvic organs are visualized more easily when the bladder is:

A. Full for transabdominal and empty for transvaginal.
B. Empty for transabdominal and full for transvaginal.
C Full for both.
D. Empty for both.

3. You are evaluating an otherwise healthy 27-year-old female who was the restrained passenger in a head-on motor vehicle accident at 45 mph. She complains of diffuse abdominal pain and a need to urinate in the trauma bay on evaluation. A Focused Assessment with Sonography in Trauma (FAST) exam during initial evaluation is negative, but computed tomography (CT) of the abdomen several minutes later shows free fluid in the pelvis. Images of your bedside ultrasound are in Figure 10.2.

Figure 10.2

Which type of image artifact being visualized resulted in a false-negative FAST exam?

A. Posterior acoustic enhancement
B. Mirror artifact
C. Reverberation artifact
D. Anisotropy

4. A 27-year-old female with a history of large ovarian cysts presents for acute onset of left lower quadrant abdominal pain that began 45 minutes prior to arrival. You are concerned for ovarian torsion and quickly perform a bedside transvaginal ultrasound of the ovaries. Which of the following modalities is the best choice to assess for this concerning pathology?

A. M-mode
B. B-mode
C. Doppler
D. High gain

5. A 22-year-old female presents with lower left abdominal pain for the last 2 days. She states she has had some vaginal spotting since yesterday as well but is not due to start her period for another week. She is sexually active but denies vaginal discharge, fever, vomiting, nausea, or abdominal distention. A pregnancy test is negative and a pelvic exam reveals no discharge, cervical motion tenderness (CMT), or adnexal tenderness. A transvaginal ultrasound is obtained as part of her evaluation. What finding seen in Figure 10.3 is the likely cause of her symptoms?

Figure 10.3

A. Simple cyst
B. Nabothian cyst
C. Hemorrhagic cyst
D. Polycystic ovarian syndrome

6. You are supervising during an afternoon shift in the ED when one of the junior residents presents a case of a 25-year-old female with left lower abdominal pain. He eagerly tells you her pain has been present for 2 days, was gradual in onset, and was without associated symptoms. He states there has been no fever, vaginal bleeding, vomiting, or other history of similar symptoms. He states that the pregnancy test is negative, a pelvic exam shows no adnexal tenderness or CMT, and the remainder of the exam is "normal." He says that he did a transvaginal ultrasound to look for ovarian cysts and interpreted the image in Figure 10.4 as a normal left ovary.

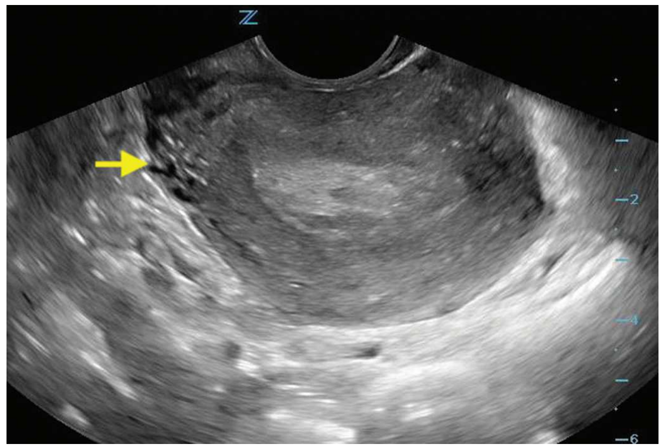

Figure 10.4

Which of the following is seen in Figure 10.4 (arrow) and can often be mistaken for ovaries?

A. Pyosalpinx
B. Hydrosalpinx
C. Periuterine vessels
D. Cyst

7. A 26-year-old female presents with diffuse abdominal pain, hypotension, and presyncope. She is tachycardic and has diffuse abdominal tenderness with guarding, and a point-of-care pregnancy test is positive. Out of concern for ectopic pregnancy, bedside ultrasound of the abdomen is performed. In what location would you most likely first see free fluid on bedside ultrasound of the pelvis?

A. Lateral to the uterus
B. Rectouterine pouch (pouch of Douglas)
C. Morrison's pouch
D. Anterior to the bladder

8. A 21-year-old nonpregnant female comes to the ED for evaluation of continued vaginal bleeding for 1 week. As part of her evaluation a transvaginal ultrasound of the pelvis is obtained. What is identified in the image in Figure 10.5?

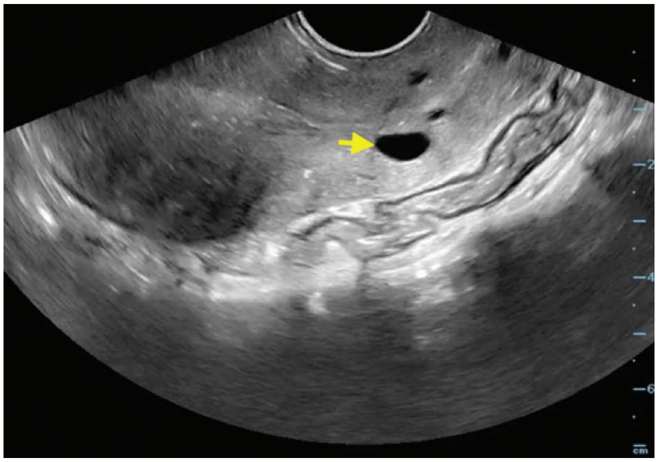

Figure 10.5

A. Nabothian cyst
B. Hemorrhagic cyst
C. Cervical ectopic
D. Ovarian cyst

9. A 31-year-old female presents for evaluation of left lower abdominal pain and fever with intermittent vaginal discharge for the last 1 week. She states that her pain is gradually worsening and she developed fever and chills yesterday. She admits to unprotected intercourse with multiple partners and a history of sexually transmitted infection. The pelvic examination reveals left adnexal tenderness and a small amount of yellow-tinged discharge from the cervix. An ultrasound is performed to evaluate for tubo-ovarian abscess (TOA). Which of the following would improve visualization of the fallopian tubes?

A. Pyosalpinx
B. Pelvic free fluid
C. Use of transvaginal ultrasound
D. All of the above

10. A 63-year-old woman comes in with lower pelvic pain. Findings on bedside ultrasound seen in Figure 10.6 increase her risk of which of the following?

A. Postmenopausal bleeding
B. Urinary incontinence
C. Uterine prolapse
D. Pelvic inflammatory disease (PID)

11. An otherwise healthy 23-year-old female with intermittent bilateral abdominal pain over the last 6 months presents to the ED for evaluation of her symptoms. She has negative pregnancy testing and is currently pain free. She denies other symptoms. She undergoes pelvic ultrasound during the course of her evaluation

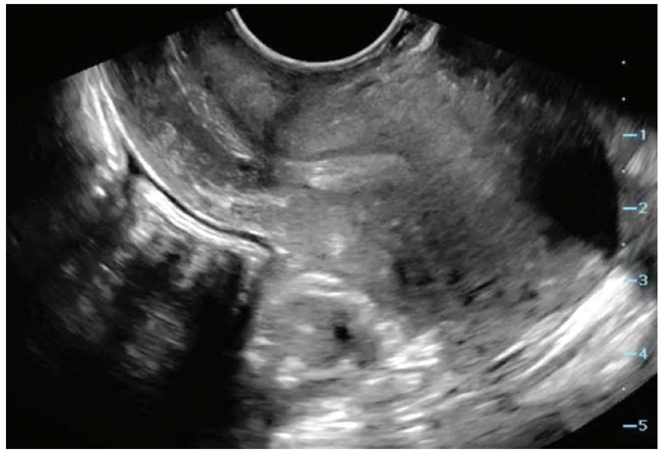

Figure 10.6

(Figure 10.7). What is the correct term for the larger hypoechoic structure demonstrated if its measurement is 2 cm?

Figure 10.7

A. Ovarian cyst
B. TOA
C. Periuterine vessel
D. Ovarian follicle

12. A postmenopausal 65-year-old female presents for evaluation of lower abdominal fullness and weight loss. She denies vaginal bleeding currently but notes intermittent "spotting" for the last 2 months. As part of her evaluation an ultrasound of the uterus was performed and the image in Figure 10.8 was obtained. What finding in this image is most concerning for malignancy in this patient?

A. Endometrial lining less than 1 mm
B. Endometrial lining 1–3 mm
C. Endometrial lining greater than 5 mm
D. None of the above

Figure 10.8

13. A postmenopausal 58-year-old female presents for evaluation of lower abdominal fullness and weight loss. She denies any vaginal bleeding or spotting at any time. The ultrasound image in Figure 10.9 is obtained as part of her evaluation.

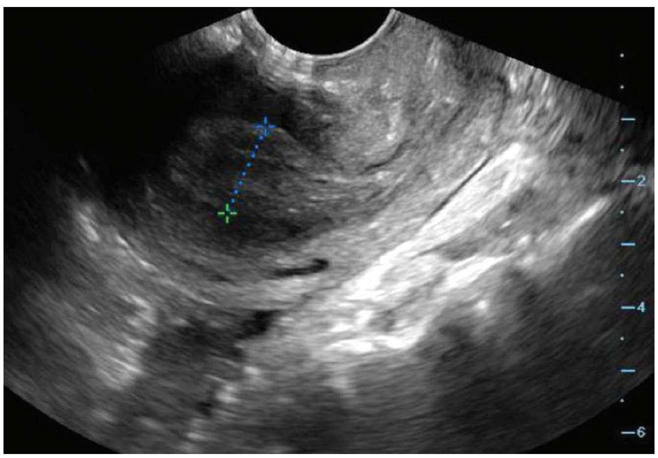

Figure 10.9

With respect to the endometrium, which of the following would be concerning for endometrial malignancy in this patient?

A. Endometrial lining greater than or equal to 5 mm
B. Endometrial lining greater than or equal to 7 mm
C. Endometrial lining greater than or equal to 9 mm
D. Endometrial lining greater than or equal to 11 mm

14. A 41-year-old female presents to the ED for pelvic pain and vaginal bleeding that started yesterday. Her vaginal bleeding is mild and urine hCG is negative. A transvaginal ultrasound is obtained that demonstrates the finding in Figure 10.10.

Based on her symptoms and the ultrasound findings, what is the most likely cause of her symptoms?

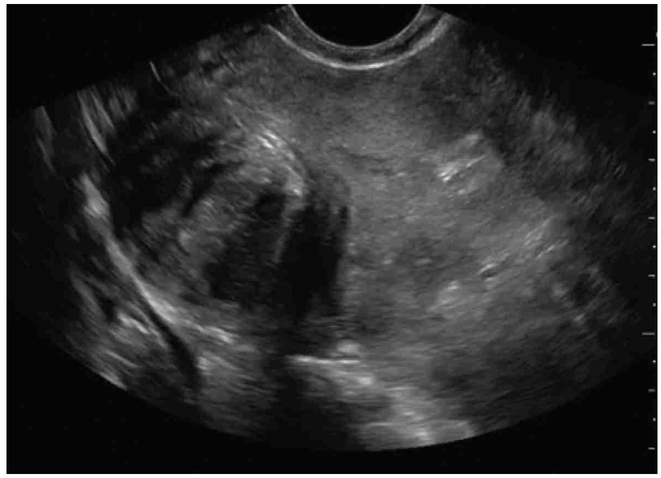

Figure 10.10

A. Dermoid cyst
B. Ovarian cancer
C. Fibroids
D. Ectopic pregnancy

15. An otherwise healthy 24-year-old female presents with lower abdominal pain intermittently for the last 3 weeks. She denies vaginal bleeding or discharge, fevers, chills, nausea, or vomiting. She is sexually active intermittently with 1 partner and seems unsure about her contraception practices. The pelvic exam reveals no adnexal tenderness, CMT, discharge, or bleeding and the abdominal examination is benign. Her pregnancy test is pending and a transvaginal ultrasound is performed at the bedside, as a transabdominal ultrasound was nondiagnostic for pregnancy.

Which of the following is seen in the image in Figure 10.11?

Figure 10.11

A. Calcified endometrium
B. Blood within the endometrium
C. IUD
D. Gestational sac

16. An otherwise healthy 33-year-old female presents to the ED with her husband. She has had periumbilical abdominal pain and vaginal spotting for the last 3 days. She states they have currently been trying to conceive for the last 2 years with 3 spontaneous first trimester abortions during that time. A urine hCG is indeterminate and her pelvic exam is normal aside from a small amount of blood in the vaginal canal. As part of her evaluation, a transvaginal pelvic ultrasound is performed (see Figure 10.12). Which of the following is seen in the image?

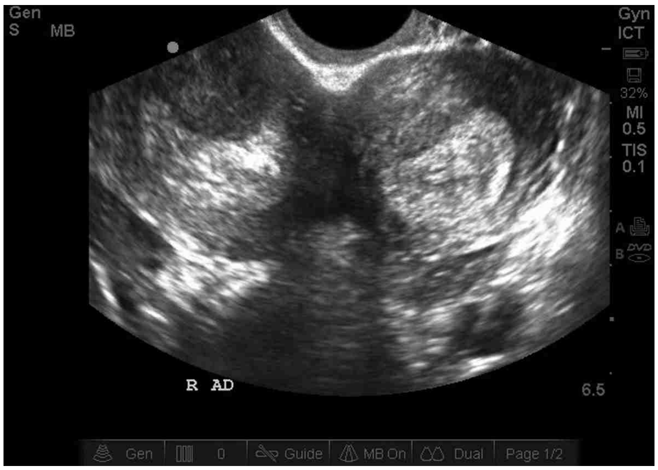

Figure 10.12

A. Mirror artifact
B. Ectopic pregnancy
C. Uterine fibroids
D. Bicornuate uterus

17. A 20-year-old female with recurrent pelvic pain presents for evaluation of bilateral lower quadrant abdominal pain that began 6 hours prior to arrival. She states that she has had similar pain before and that she has a history of "cysts" on her ovaries. As part of her evaluation a transabdominal ultrasound is performed at the bedside. Which of the following characteristics would you *not* expect to see in a physiologic ovarian cyst?

A. Septations with color Doppler flow
B. Thin walled
C. Diameter ≤3 cm
D. Posterior acoustic enhancement

18. A 19-year-old female comes to the ED with right lower abdominal pain worsening for the last 2 days. She has not had fever, the pain began semi-acutely, and she denies vaginal discharge or bleeding. Her serum pregnancy test is negative and she is not sexually active. While waiting for transvaginal ultrasound, her pain suddenly decreases without intervention. After returning from her ultrasound you notice her blood pressure is lower than previously and she has become tachycardic. Concerned, you obtain the pelvic and right upper quadrant images seen in Figure 10.13.

Based on the images, what is the most likely cause of her symptoms?

A. Ascites
B. Uterine fibroids
C. Ovarian torsion
D. Ruptured hemorrhagic ovarian cyst (HOC)

19. A 28-year-old female presents for evaluation of left lower abdominal pain with intermittent vaginal discharge for the last 1 week. She states that her pain is gradually worsening and she has developed a fever over the last 2 days. She admits to unprotected intercourse with multiple partners and past diagnosis of gonorrhea. On exam she is mildly tachycardic with tenderness in the left lower quadrant without rebound or guarding. Her pelvic exam reveals green-tinged discharge, CMT, and left adnexal tenderness. Her urine pregnancy test

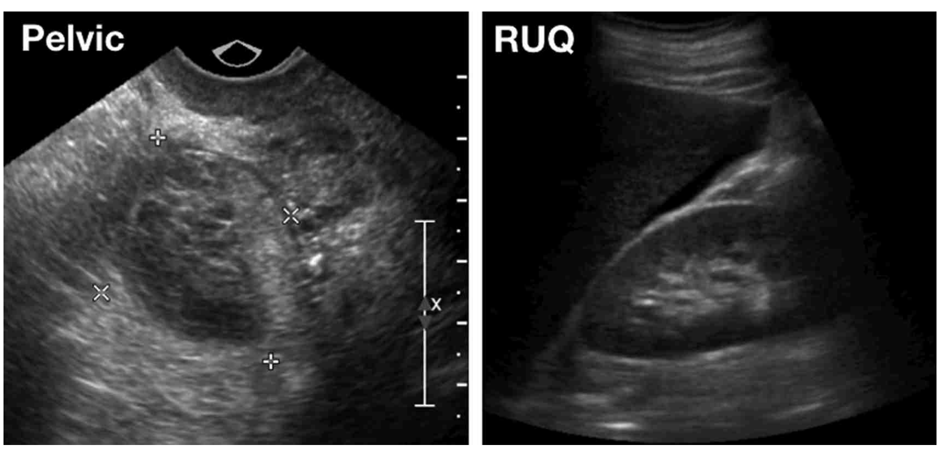

Figure 10.13

is negative. An ultrasound is performed to evaluate for TOA (Figure 10.14).

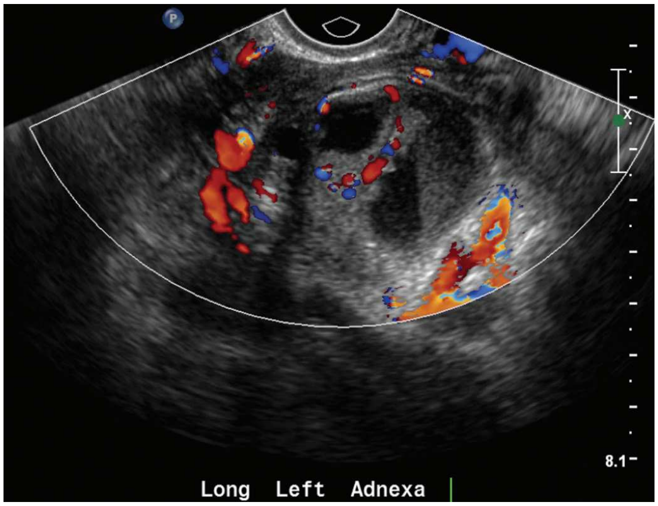

Figure 10.14 *Image courtesy of Anokh Pahwa, MD, Department of Radiology, Olive View–UCLA Medical Center, Los Angeles, CA.*

Which of the following statements are *not* true regarding ultrasound findings in TOA?

A. They are usually multiloculated.
B. They usually have low-level internal echoes.
C. It is usually easy to differentiate fallopian tube from ovary.
D. Gas within the mass is a rare finding.

20. A 15-year-old female presents with left-sided abdominal pain for the last 3 hours. She seems very uncomfortable but has no past medical history and no other symptoms. She just urinated and denies dysuria. She is not sexually active and pregnancy testing is negative. You are considering an ultrasound of the abdomen and pelvis as a possible part of her further evaluation. Which of the following is the most important factor in deciding whether to perform transabdominal pelvic ultrasound instead of transvaginal pelvic ultrasound?

A. An empty bladder improves visualization of pelvic organs transabdominally.
B. It is noninvasive.
C. It provides more detailed visualization of pelvic organs.
D. It is the preferred modality for visualizing ovarian pathology.

21. A 25-year-old female presents for evaluation of anovulation. You note hirsutism and her body mass index is 42. Which of the following ultrasound findings would be consistent with the suspected diagnosis of polycystic ovarian syndrome (PCOS)?

A. 12 or more follicles on at least 1 ovary
B. Follicles only located centrally
C. Uterine fibroids
D. 26 or more follicles on at least 1 ovary

22. A 26-year-old female with intermittent pelvic pain, back pain, and painful menses presents to the ED for evaluation. During her evaluation a transvaginal ultrasound is obtained.

Figure 10.15

What is seen in the image in Figure 10.15?

A. Teratoma
B. Ovarian cyst
C. Endometrioma
D. Ectopic pregnancy

23. A 63-year-old female presents to the ED for 2 months of increasing abdominal distention and weight loss. She undergoes transabdominal pelvic ultrasound and the image in Figure 10.16 of a right ovarian mass is obtained. It shows a mass on the right ovary (O) as well as extension to the uterus (U) on the left.

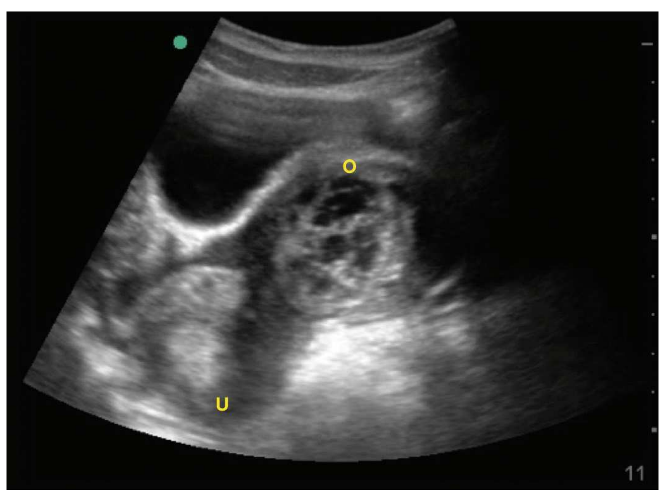

Figure 10.16

If her mass is an ovarian malignancy with extension to the uterus, what stage would her cancer be, based on FIGO criteria?

A. At least stage 1
B. At least stage 2
C. At least stage 3
D. At least stage 4

24. You are using transabdominal ultrasound to evaluate a 24-year-old female complaining of atraumatic abdominal pain, tachycardia, and hypotension. Pregnancy status and LMP are unknown and pregnancy testing is currently pending. This transabdominal pelvic image is obtained and shown in Figure 10.17.

Figure 10.17

What additional anatomic area should also be imaged given the patient's symptoms and the findings in the image?

Figure 10.18 *Image courtesy of Shaden Mohammad, MD, and Monica Deshmukh, MD, Department of Radiology, Olive View–UCLA Medical Center, Los Angeles, CA.*

A. The left upper quadrant
B. The lungs
C. Right upper quadrant (Morrison's pouch)
D. The pouch of Douglas transvaginally

25. A 58-year-old female presents with intermittent left lower abdominal and pelvic pain for the last week. The pain today was gradual in onset and constant. She states that her abdomen feels slightly larger but thinks that she has lost weight. She has not had fevers, vaginal discharge, vaginal bleeding, nausea, or vomiting. She is not sexually active and her LMP was approximately 8 years ago. A pelvic exam is normal and a transvaginal ultrasound obtained as part of the evaluation yields the image in Figure 10.18. Which structure seen in the image is most concerning for malignancy in this patient?

A. Corpus luteum cyst
B. Simple cyst

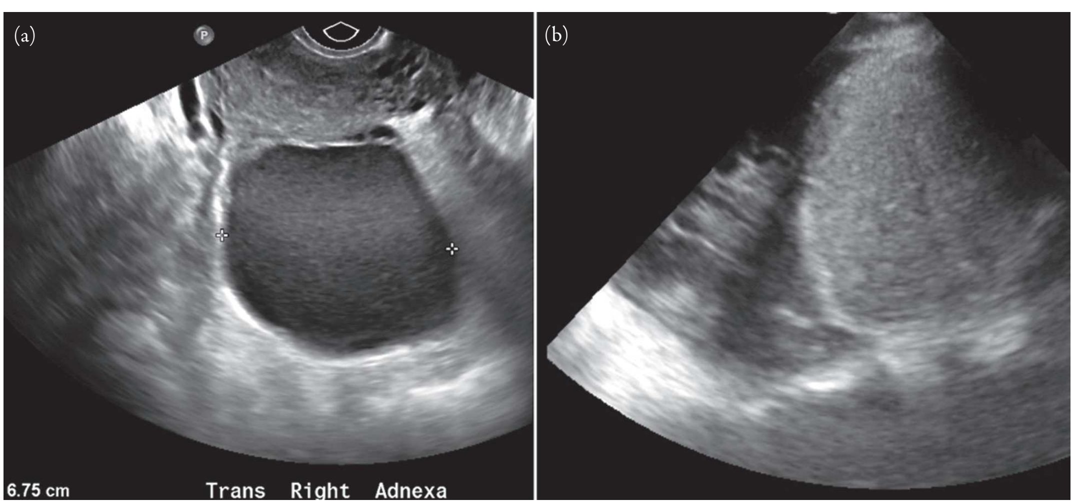

Figure 10.19 (a) *Image courtesy of Anokh Pahwa, MD, Department of Radiology, Olive View–UCLA Medical Center, Los Angeles, CA.*

C. Hemorrhagic ovarian cyst
D. PCOS

26. A 27 year-old female presents with recurrent pelvic pain for the past several months. It occurs about a week after her period and is primarily left-sided. She also has noticed some pleuritic chest pain that is worse during these intervals as well. On exam, she looks well and has normal breath sounds but has lower left quadrant tenderness to palpation. Her pelvic exam is normal except for some left adnexal fullness and mild tenderness. Her urine pregnancy test is negative. You perform the following ultrasounds shown in Figure 10.19.

You suspect an endometrioma. What is true of endometriosis?

A. Laparoscopy is the gold standard for diagnosis.
B. It rarely affects the pulmonary and central nervous systems.
C. It commonly spreads to adjacent peritoneal and retroperitoneal structures.
D. All of the above.

27. A 37-year-old female presents with recurrent pelvic pain and heavy menstrual bleeding. She says that the symptoms have worsened over the past year. She has a negative urine point-of-care pregnancy test. Her exam is notable for an enlarged, mildly tender uterus on exam with some scant blood in the vault but a normal appearing cervix without CMT, discharge, or adnexal tenderness.

What ultrasound findings would suggest adenomyosis?

A. Irregular endometrial-myometrial border
B. Asymmetric thickening of the myometrium
C. Evidence of tiny cysts in the myometrium
D. All of the above

ANSWERS

1. EXPLANATION

A. Can be normal dependent on the patient's menstrual cycle. The image (Figure 10.1) shows a small amount of pelvic free fluid, which can be a normal finding in the pelvis throughout the menstrual cycle. Fluid is most common in the 5 days before the onset of menses. The presence of the fluid is thought to be due to hormone mediated increased capillary permeability. The posterior cul-de-sac (pouch of Douglas) is a potential space that commonly contains small amounts of fluid, as it is the most dependent part of the pelvis. The anterior cul-de-sac is not a dependent space and does not commonly contain free fluid unless significant amounts are present. While small amounts of physiologic free fluid can be normal, it is important to remember that other processes, such as hemorrhagic cyst rupture and ruptured ectopic pregnancy, can also present with findings of pelvic free fluid.

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Keywords/Tags: Gyn, interpretation

Learning Point 1: Small free fluid in the pelvis, especially in the pouch of Douglas, can be a normal part of the menstrual cycle.

2. EXPLANATION

A. Full for transabdominal and empty for transvaginal. The uterus is surrounded by bowel and it can be difficult to image via a transabdominal approach. A filled bladder provides an acoustic window for transabdominal pelvic ultrasound and helps straighten an anteverted uterus by moving it posteriorly. Transvaginal ultrasound is performed with an empty bladder as a full bladder can move the uterus and adnexal structures further away from the transducer, impairing image quality and increasing image artifacts (see Figure 9.20).

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Keywords/Tags: Gyn, acquisition

Learning Point 2: Pelvic organ visualization is enhanced transvaginally when the bladder is empty and transabdominally when the bladder is full.

3. EXPLANATION

A. Posterior acoustic enhancement. This is a sonographic artifact that occurs when sound waves pass through mediums or structures with low attenuation (i.e., fluid). As sound waves pass through these low attenuation areas, less sound energy is lost compared to surrounding tissue, and objects immediately deep to these low attenuating structures appear more hyperechoic than surrounding structures. The bladder and simple cysts are examples of fluid-filled pelvic structures where this is frequently seen. Increased echogenicity caused by posterior acoustic enhancement can impair visualization of fluid, organs, or areas of interest posterior to these structures. In the first image, the area deep to the bladder is obscured by high gain and posterior acoustic enhancement (Figure 10.2). It is better seen in the second image after adjustment of far-field gain to account for the posterior acoustic enhancement (Figure 10.20).

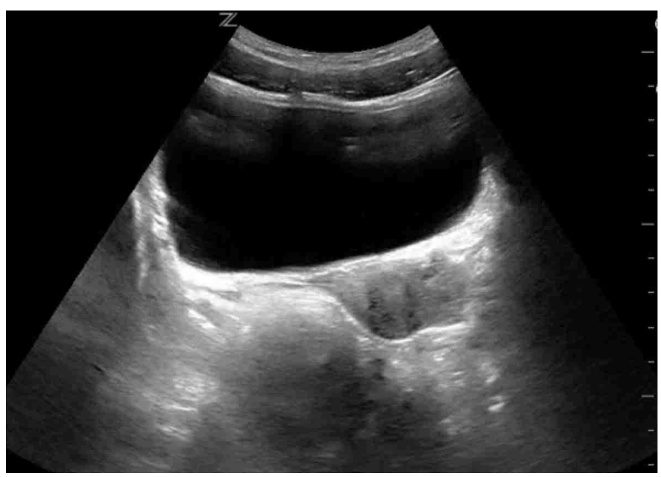

Figure 10.20 **Adjusting the gain to minimize posterior acoustic enhancement.** An echogenic cystic mass is seen posterior lateral to the bladder.

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Keywords: posterior acoustic enhancement

Learning Point 3: Posterior acoustic enhancement can lead to pelvic free fluid, pelvic organs, or other structures being obscured.

4. EXPLANATION

C. Doppler. When ovarian torsion is suspected, color Doppler should be used to assess for flow inside the ovary and spectral Doppler should be used to assess for both normal arterial and venous waveforms. The most common Doppler finding in torsion is decreased or absent venous flow, which is seen in 93% of cases as the venous system is often occluded before the higher pressure arterial system. Since the ovary has dual blood supply from ovarian and uterine arteries, there may be flow in one portion of the ovary but not another. Lack of arterial flow, particularly central flow, is highly specific for torsion with positive predictive values as high as 94%.

Figure 10.21a shows peripheral arterial flow on pulsed wave Doppler of an ovary with intermittent torsion. The presence of both arterial and venous flow does not rule-out torsion. In intermittent torsion, flow may be demonstrated on ultrasound if there is no active torsion at the time the exam is performed.

2D gray-scale imaging findings associated with torsion include

- Unilateral ovarian enlargement (>4 cm diameter).
- Pelvic free fluid.
- A string of pearls sign (central edema with peripheral follicles; Figure 10.21b).
- A whirlpool sign that is seen with twisting of the vascular pedicle (Figure 10.22).
- An ovarian mass or cyst that can act as a fulcrum for the ovary to twist upon.

The diagnosis of torsion should be pursued despite normal appearing Doppler ultrasound if the clinical suspicion is high and/or there are findings associated with torsion on 2D gray-scale ultrasound of the ovary.

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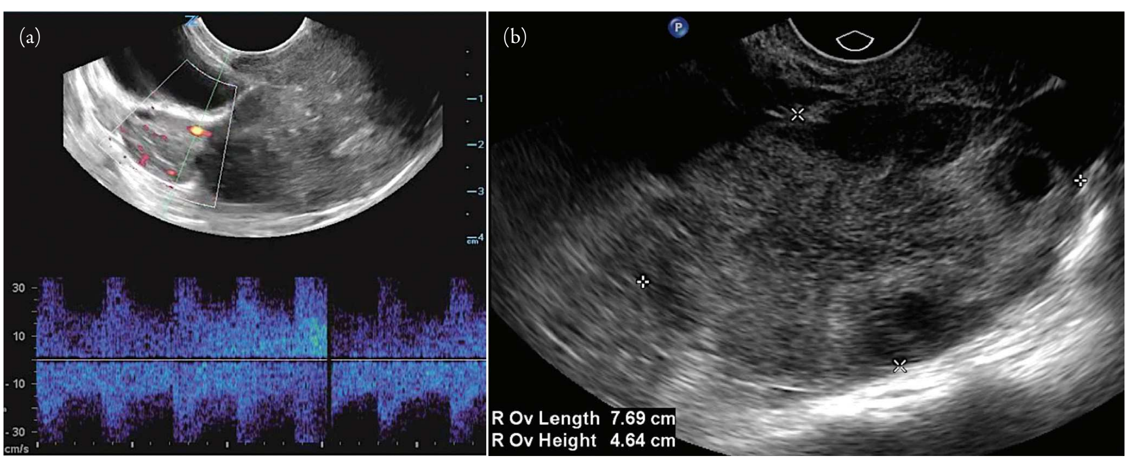

Figure 10.21 (a) **Color power Doppler with pulsed waved Doppler showing peripheral arterial flow in a patient with intermittent ovarian torsion.** (b) **String of pearls sign in ovarian torsion.** The ovarian is enlarged and edematous centrally due to vascular and lymph congestion, with the peripheral follicles forming a ring or string of pearls sign. *Image courtesy of Shaden Mohammad, MD, and Monica Deshmukh, MD, Department of Radiology, Olive View–UCLA Medical Center, Los Angeles, CA.*

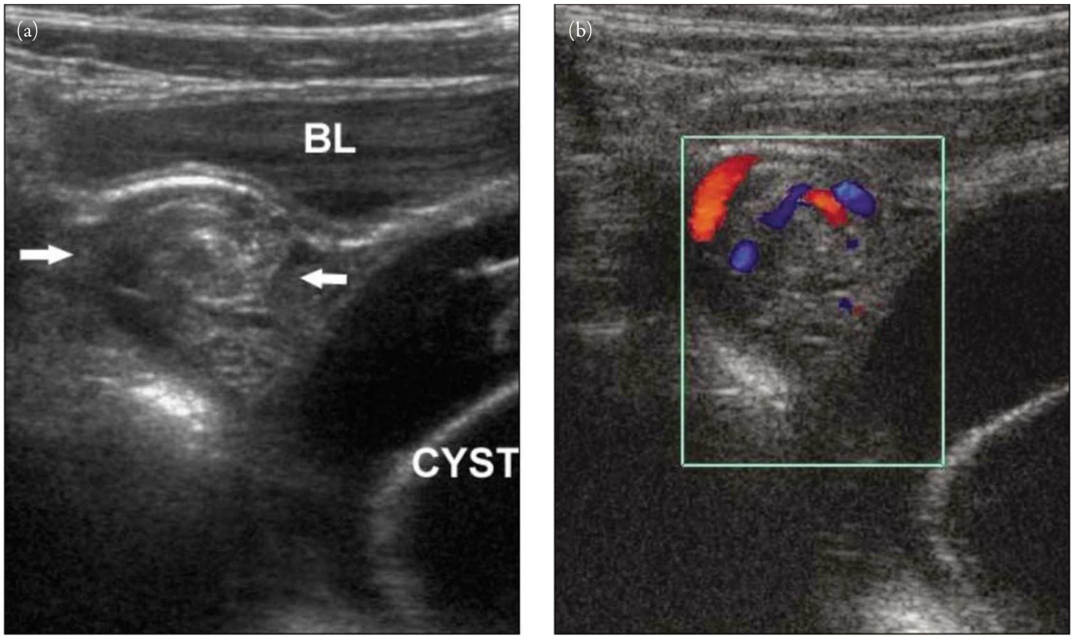

Figure 10.22 **Whirlpool sign in ovarian torsion.** The vascular pedicle of the ovary is twisted, forming this hypoechoic mass (arrows in Panel (a)). The bladder (BL) is above, while a cyst is seen, serving as a fulcrum for the ovary to twist. On color Doppler, there is a twisting of vascular flow (Panel (b)). Adapted from Figure 3 of Vijayaraghavan SB. Sonographic whirlpool sign in ovarian torsion. *J Ultrasound Med*. 2004;23:1643–1649.

Keywords: ovarian torsion, string of pearls sign, whirlpool sign

Learning Point 4: Ovarian torsion is associated with a unilaterally enlarged ovary (>4 cm), pelvic free fluid, adnexal mass, and a string of pearls sign. Absence of flow on Doppler is highly suggestive of torsion; however, presence of flow does not rule out torsion.

5. EXPLANATION

C. Hemorrhagic cyst. The ultrasound image demonstrates a hemorrhagic ovarian cyst (HOC). HOCs develop typically from corpus luteal cysts, which contain a thin, highly vascularized layer of granulosa cells. When vessels in this layer rupture, there is bleeding into the cyst, which evolves into either a reticular fish-like pattern or a retracted clot pattern. Figure 10.3 shows a classic fishnet pattern of a HOC, while Figure 10.23 shows a corpus luteal cyst in the same patient 2 days prior, showing some internal echoes signifying the early development of a HOC. HOCs will typically resolve over time, but when they rupture, this can lead to complications as severe as hemoperitoneum. While HOCs may mimic other pathologies, a woman of reproductive age presenting in the luteal phase, with a negative pregnancy test, and this cystic pattern on pelvic ultrasound is likely to have a HOC. Nabothian cysts are found in the uterus and are not depicted in this image. A single large cyst is not characteristic of polycystic ovarian syndrome (PCOS) where large amounts of small cysts are seen throughout the ovary.

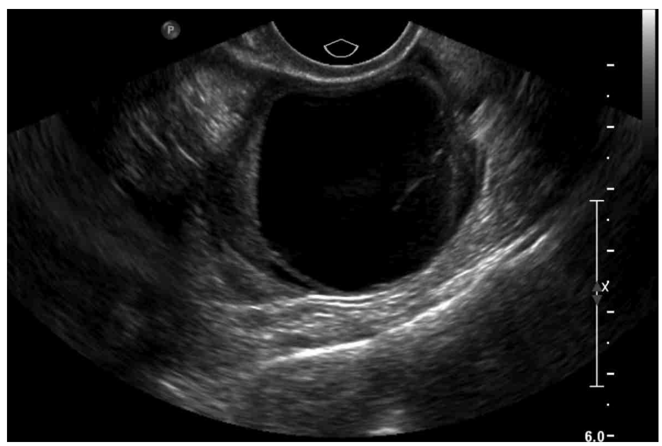

Figure 10.23 **Early hemorrhagic ovarian cyst.** This is a corpus luteal cyst with rupture of the highly vascular granulosa layer, leading to bleeding into the cyst. There are some internal echoes seen, signifying clotting blood.

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Keywords: hemorrhagic ovarian cyst, Nabothian cyst, corpus luteum

Learning Point 5: Hemorrhagic ovarian cysts can be differentiated from other cystic ovarian structures by the presence of low-level internal echoes, lack of internal vascularity, and reticular or lace-like pattern of internal echoes. They typically develop from ruptured blood vessels surrounding a corpus luteal cyst.

6. EXPLANATION

C. Periuterine vessels. This image shows periuterine vasculature (arrow), best seen as the small hypoechoic areas on the left edge of the uterus in this image. Novice learners can mistake periuterine vasculature for ovaries, as both can have small anechoic areas. Pelvic and periuterine vasculature can vary in size and appearance especially if pelvic venous insufficiency (PVI) or pelvic venous congestion are present. PVI is diagnosed by various characteristics including dilated pelvic veins >4 mm (arrow) and slowed venous blood flow (Figure 10.24a). PVI is analogous to varicoceles in men, with report of pain associated with standing and at the end of the day. Treatment may be medical, via suppressing ovarian function, or surgical, typically with embolization of the affected veins.

Normal ovaries and fallopian tubes are difficult to see on transabdominal ultrasound, and their visualization should raise concern for pathologic processes such as hydrosalpinx or pyosalpinx, neither of which is seen here. Hydrosalpinx appears as a linear hypoechoic structure that can be thin or thick walled (Figure 10.24b). Pyosalpinx will appear similarly and may also have low-level internal echoes from debris or pus. Transvaginal ultrasound is best for visualizing the fallopian tubes, ovaries, and any pathology associated with them.

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Keywords: periuterine vessels, hydrosalpinx, pyosalpinx, pelvic vein insufficiency

Learning Point 6: Hydrosalpinx, pyosalpinx, and dilated periuterine vessels may appear similarly.

7. EXPLANATION

B. Rectouterine pouch (pouch of Douglas). The pouch of Douglas, also known as the rectouterine pouch, is a dependent, potential space bounded by the uterus anteriorly and the sigmoid colon posteriorly. Small amounts of physiologic free fluid are commonly found here throughout the menstrual cycle but, given the dependent nature of the area, this is the likely first place of accumulation of larger amounts of pathologic free fluid. Fluid may accumulate in the areas described by the other answer choices but is most likely to develop first in the rectouterine pouch in a ruptured ectopic pregnancy. If there is high concern for pathologic pelvic free fluid, transvaginal ultrasound should be strongly considered, as it is more sensitive for visualization of fluid in this area than transabdominal ultrasound (see Figure 10.1).

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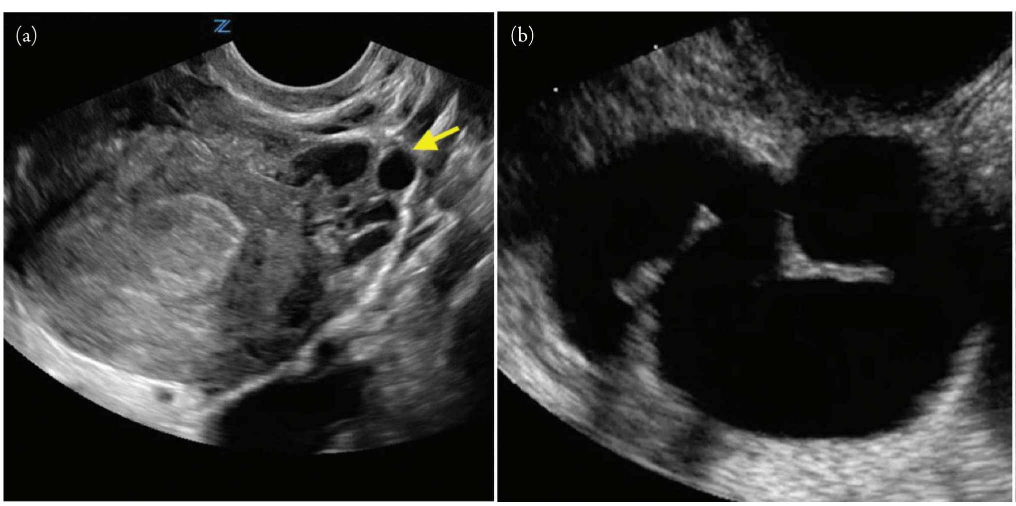

Figure 10.24 (a) **Dilated periuterine vessels from pelvic vein insufficiency.** (b) **Hydrosalpinx.**

Keywords/Tags: Pouch of Douglas, Abdominal Free Fluid

Learning Point 7: Free fluid in the pelvis is most easily seen on the longitudinal view of the pouch of Douglas.

8. EXPLANATION

A. Nabothian cysts. These are often incidentally found hypoechoic cystic structures of the cervix. They can form after cervicitis, childbirth, or other inflammatory processes where mucinous epithelium becomes trapped under other epithelial layers. They can range in size from a few millimeters to 4 cm and can cause symptoms of vaginal pressure, fullness, or dyspareunia. Adenomyosis can have a similar appearance but is located in the myometrium, is often distributed more diffusely, and often manifests with painful menses. Fibroids can be found in the cervix but do not appear cystic as they arise from uterine smooth muscle cells. Nabothian cysts lack the hyperechoic complex fluid seen in hemorrhagic cysts, and they can be differentiated from cervical ectopic pregnancies by the lack of a gestational sac and fetal pole.

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Keywords/Tags: Nabothian cyst

Learning Point 8: Nabothian cysts are a common, normal finding in the lower uterine segment and cervix of young women.

9. EXPLANATION

D. All of the above. The fallopian tubes are often not visualized in the absence of pathology but are best seen with transvaginal ultrasound due to their small size. They can sometimes be detected by assessing for the cornual flare sign, the junction of the uterus and fallopian tube (Figure 10.25). The cornual flare can also be helpful in locating the ovaries. The cornual flare can be assessed by rotating the transducer to a coronal or transverse plane of the uterus, then fanning or tilting superiorly to the uterine fundus. At this point the isthmus and fallopian tubes will be visualized, and the transducer can then be angled laterally to find the ovaries. The presence of fluid or pus in the fallopian tubes (hydrosalpinx or pyosalpinx) enhances visualization of the fallopian tubes as does free fluid surrounding the pelvic organs. Clearly visualized fallopian tubes and lumens should be concerning for a pathologic process (Figure 10.24).

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Keywords/Tags: Gyn, acquisition, cornual flare sign

Learning Point 9: Fallopian tube visualization is best obtained transvaginally in a coronal plane by identifying the cornua. Visualization of the fallopian tubes is made easier by pathology such as fluid or pus inside or surrounding the fallopian tube.

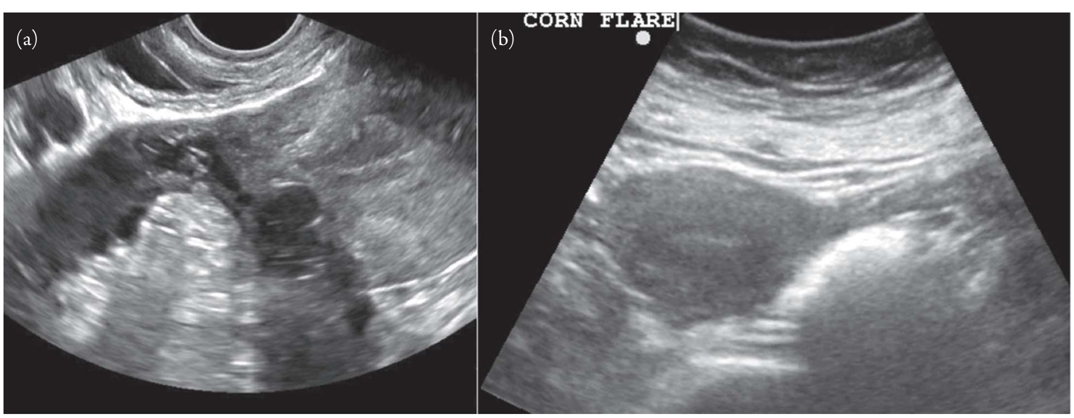

Figure 10.25 (a) **Cornual flare sign on transvaginal ultrasound.** (b) **Cornual flare sign on transabdominal ultrasound.**

10. EXPLANATION

C. Uterine prolapse. Retroverted uterus is found in 20% of the population and is most easily identified in the longitudinal axis transvaginally. Visualization of the uterine fundus lying posterior in the pelvis away from the bladder on a sagittal view is indicative of retroverted uterus. Women with retroverted uterus are 4.5 times more likely to have uterine prolapse than women without. Prolapse does not increase the incidence of PID, urinary incontinence, or postmenopausal bleeding.

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Keywords/Tags: Uterine Prolapse, Pelvic Pain, Retroverted Uterus

Learning Point 10: Retroverted uterus is found in 20% of the population and is most easily identified in the longitudinal axis transvaginally by visualization of the uterine fundus lying posteriorly in the pelvis, away from the bladder.

11. EXPLANATION

D. Ovarian follicle. Most ovarian follicles are between 1 cm and 2.5 cm in diameter with the dominant follicles being on the higher end of this range. The term *follicular cyst* is used when the follicle enlarges to 3 cm or more. This can occur when follicles fail to release an oocyte or fail to involute as they regress. Ovarian cysts are differentiated from para-ovarian or para-tubal cysts in that they arise directly from the ovary itself (Figure 10.26, Video 10.1).

Figure 10.26 **Simple ovarian cyst seen on transvaginal ultrasound.**

Some commonly encountered types of ovarian cysts are presented in Table 10.1.

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Keywords: ovarian follicle, follicular cyst, para-ovarian cyst

Learning Point 11: Normal ovarian follicles measure less than 3 cm and are considered follicular cysts if more than 3 cm.

12. EXPLANATION

C. Endometrial lining greater than 5 mm. The correlation between endometrial thickness and likelihood of endometrial malignancy in postmenopausal women varies based on the presence or absence of vaginal bleeding. After menopause, lack of estrogen causes thinning and atrophy of the endometrium. Endometrial thickening in postmenopausal women runs counter to this postmenopausal physiology and can be due to endometrial hyperplasia, tumor tissue, or thickening in response to an estrogen secreting neoplasm. In a 2004 meta-analysis, the risk of endometrial cancer in women with postmenopausal bleeding and a thickened endometrium (>5 mm) was approximately 7.3%. For these reasons an endometrial thickness greater than or equal to 5 mm in a postmenopausal patient with vaginal bleeding mandates endometrial biopsy or other further testing for endometrial malignancy (Figure 10.27a).

To measure the endometrial thickness, a sagittal plane of the endometrial lining is obtained at the maximal thickness to avoid cylinder tangent effect. Measurement should be obtained in a perpendicular axis of the thickest segment of the endometrium. Calipers should be placed on the outer edges of the "halo" formed by the endometrial lining (Figure 10.27b).

Table 10.1. CHARACTERISTICS OF OVARIAN FOLLICLES AND CYSTS

	SIZE	FEATURES	SIMPLE/ COMPLEX
Ovarian follicle	**<2.5–3 cm**	**Anechoic, rounded cystic structure, smooth thin walls, no internal vascularity**	**Simple**
Simple ovarian cyst	**>3 cm**	**Anechoic, rounded cystic structure, smooth thin walls, no internal vascularity**	**Simple**
Hemorrhagic ovarian cyst	**Variable**	**Rounded structure, low level lace-like/reticular internal echoes, thin walled, no internal vascularity**	**Complex**
Dermoid cyst (Mature cystic teratoma)	**Variable**	**Variable hyperechoic components, possible acoustic shadowing, fluid-fluid levels, no internal vascularity**	**Complex**
Endometrioma	**Variable**	**Variable appearance. Homogenous internal echoes due to hemorrhagic debris, unilocular cystic structure, no internal vascularity**	**Complex**

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Keywords/Tags: Vaginal Bleeding, Menopause, Endometrial Thickness

Learning Point 12: Endometrial lining over 5 mm in postmenopausal women with vaginal bleeding is concerning for endometrial cancer.

13. EXPLANATION

D. Endometrial lining greater than or equal to 11 mm. Even in the absence of vaginal bleeding in a postmenopausal female, endometrial thickening greater than or equal to 11 mm is concerning for potential malignancy and should be evaluated. After menopause the endometrium atrophies due to the loss of stimulation by estrogen release. Endometrial thickening in this population can be due to hyperplasia, tumor, or as a response to estrogen secreting neoplasm. Postmenopausal patients with endometrial thickening to this degree require further evaluation, usually with endometrial biopsy to evaluate for malignancy.

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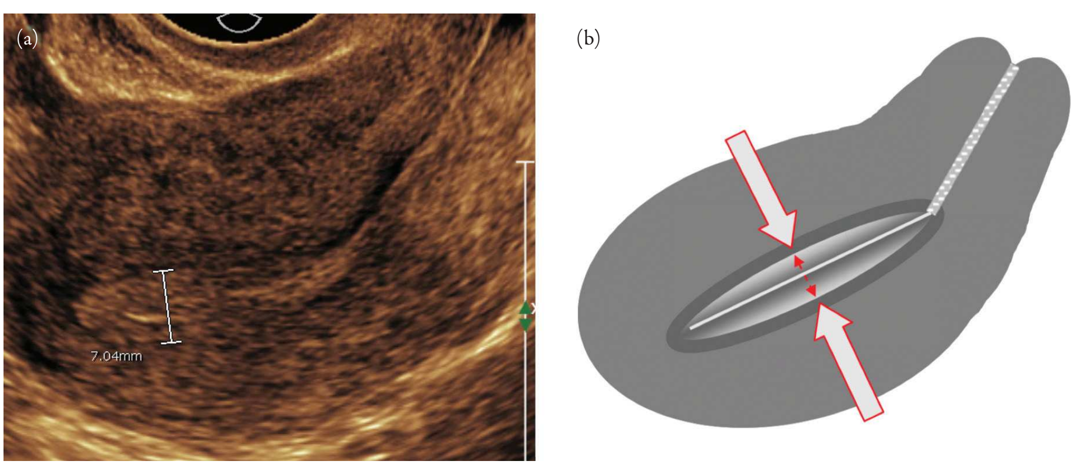

Figure 10.27 (a) **Thickened endometrial stripe in sepia tone on transvaginal ultrasound.** (b) **Measurement of endometrial lining.** Adapted from Figure 1 of Bignardi T, Van den Bosch T, Condous G. Abnormal uterine and post-menopausal bleeding in the acute gynaecology unit. *Best Pract Res Clin Obstet Gynaecol*. 2009;23(5):595–607. doi:10.1016/j.bpobgyn.2009.05.001.

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Keywords/Tags: Endometrial Thickness, Endometrial Malignancy

Learning Point 13: Endometrial lining over 11 mm in postmenopausal women without vaginal bleeding is concerning for endometrial cancer.

14. EXPLANATION

C. Fibroids. Also called leiomyomas, fibroids are the most common benign pelvic tumor and the most common pelvic tumor overall. They originate from the myometrium and are classified according to location (Table 10.2). The ultrasound in this case is a Federation of Gynecology and Obstetrics (FIGO) type 3 fibroid as it primarily involves the myometrium with contact of the endometrium. They are more commonly seen in African American women and are important to recognize, as they are associated with pelvic pain, heavy menstrual bleeding, infertility, and pregnancy loss.

Ultrasound is the initial test of choice for evaluation of suspected fibroids. When seen on ultrasound they have a heterogeneous appearance within or adjacent to the uterus and often have internal calcifications. Magnetic resonance imaging (MRI) can also be used for further evaluation of fibroids if ultrasound is insufficient.

There are a number of nonsurgical treatments for fibroids and their symptoms including tranexamic acid, nonsteroidal anti-inflammatory drugs (NSAIDs), levonorgestrel-releasing intrauterine devices (IUDs), and gonadotropin-releasing hormone agonists. The latter treatment currently is the most effective in reducing fibroid volume and heavy menstrual bleeding. However, surgical therapies such as myomectomy in the premenopausal patient and hysterectomy in the postmenopausal patient are still widely used in treating fibroids.

Table 10.2. **FEDERATION OF GYNECOLOGY AND OBSTETRICS CLASSIFICATION FOR FIBROIDS**

LOCATION	TYPE	DESCRIPTION
Submucosal	0	Intercavitary and pedunculated
	1	<50% intramural
Submucosal and Subserosal	2	>50% intramural
	3	Contacts endometrium and 100% intramural
	4	Intramural
	5	Subserosal, >50% intramural
Subserosal	6	Subserosal, <50% intramural
	7	Subserosal pedunculated
Other	8	Other (e.g., cervical)

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Keywords/Tags: Fibroids

Learning Point 14: Features of a fibroid include heterogeneous appearance, calcifications, and locations within the subserosal, intramural, or myometrial layers. Fibroids have streaking attenuation artifacts often obscuring other structures.

15. EXPLANATION

C. IUD. These are usually strongly echogenic and easily identified on transvaginal ultrasound if located within the uterus. The majority are "T" shaped; however, older "S" or circle-shaped versions may also be encountered in older patients. While many IUDs are primarily metal, some types have portions that are less echogenic, particularly the arms of the levonorgestrel-releasing IUDs. Occasionally IUDs can be difficult to distinguish from the more echoic endometrial stripe on transabdominal ultrasound. More recently, 3D ultrasound reconstructions have been used to increase visualization of IUD that may be embedded in myometrium. However, this option is not widely available on many point-of-care ultrasound machines, and advanced imaging such as CT or MRI may be required if there is concern the patient may have an IUD that is displaced, embedded, or perforated.

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Keywords/Tags: Intrauterine Device, IUD

Learning Point 15: IUD appears as an echogenic, linear projection, often with reverberation artifact in the uterine stripe.

16. EXPLANATION

D. Bicornuate uterus. The image shows a bicornuate uterus on a coronal plane using transvaginal ultrasound. Bicornuate uterus is a rare congenital abnormality found in approximately 0.4% of women. While the probability of natural pregnancy in patients with bicornuate uterus is not statistically different than in unaffected individuals, there is an increased incidence of spontaneous first trimester abortion in women with bicornuate uterus based on results of a recent meta-analysis. However, it is often difficult to distinguish a bicornuate uterus from a septate uterus, with the latter having a stronger association with fertility complications (Figure 10.28). Further imaging such as with 3D ultrasound or MRI, along with specialist consultation, should be obtained.

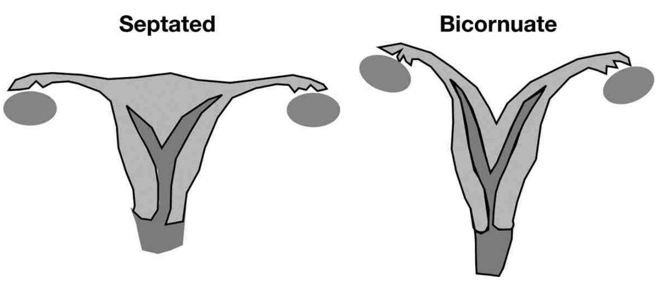

Figure 10.28 **Septated uterus versus bicornuate uterus.**

Ectopic pregnancy is incorrect as there is no evidence of a gestational sac in this ultrasound image. There are no areas of isoechoic or hypoechoic mass to suggest fibroids. Mirror artifact is a tempting choice and is seen when ultrasound waves hit a strong reflective surface that alters the course of the reflected beam, causing incorrect signal interpretation. Here there is no highly echogenic reflector to create a duplicate image, and, further, the fact that the images are not identical supports that these are 2 distinct uterine structures.

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Keywords/Tags: Bicornuate Uterus, septated uterus

Learning Point 16: Bicornuate uterus is a uterus composed of 2 uterine “horns” separated by a septum.

17. EXPLANATION

A. Septations with color Doppler flow. Simple physiologic cysts of the ovary are anechoic, thin walled, and ≤3 cm in diameter. Because they are fluid filled they will also demonstrate posterior acoustic enhancement. Functional cysts are ovarian cysts that produce hormones but exceed the 3 cm size criteria. These include estrogen-producing follicular cysts, progesterone-producing corpus luteal cysts, and theca lutein cysts in patients with gestational trophoblastic disease. Presence of septations, internal vascularity, internal echoes, irregular walls, and lack of posterior acoustic enhancement are characteristics of complex cysts (Figure 10.29). Hemorrhagic ovarian cysts, endometriomas, and cystic teratomas are

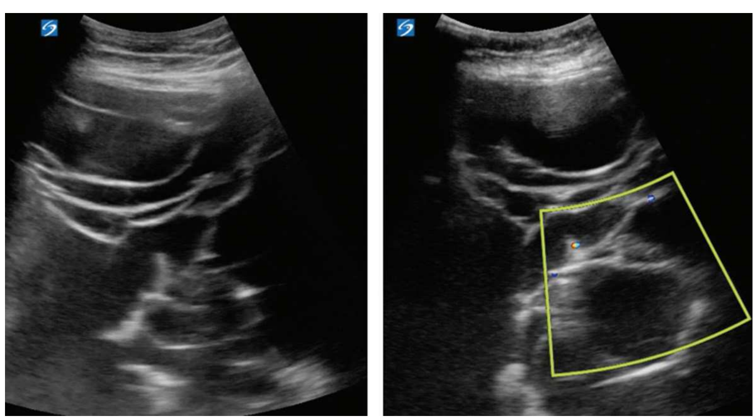

Figure 10.29 **Complex ovarian cyst on transabdominal ultrasound.** This cyst measured over 10 cm in diameter and features multiple septae of variable thickness. On color Doppler, there is flow within some of the septae. This cyst was removed and diagnosed as a serous cystadenocarcinoma on pathology.

examples of typically benign complex cysts. In particular, cysts with multiple, thick, or vascular septations are concerning for possible neoplasm and may need further evaluation.

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Keywords/Tags: Ovarian Cysts

Learning Point 17: Simple ovarian cysts are anechoic, thin walled, and ≤3 cm in diameter.

18. EXPLANATION

D. Ruptured HOC. HOCs are a common cause of gynecologic pain in the nonpregnant premenopausal female. Hemorrhagic cysts appear similar to simple cysts but can be larger and have low-level internal echoes and very thin lace-like fibrin septations. Pain is usually acute, unilateral, and maximal at onset. Normally, they will resolve along with symptoms in a matter of a few weeks. However, if a large HOC ruptures, patients may develop hemoperitoneum in the pelvis and the upper abdomen including in Morrison's pouch. Patients with large amounts of hemoperitoneum can present with peritonitis, syncope, tachycardia, and/or hypotension. It is important to also consider other diagnoses such as ruptured ectopic pregnancy, ruptured appendicitis, TOA, or ruptured diverticulitis in patients with symptoms consistent with a ruptured ovarian cyst.

Figure 10.30 and Video 10.2 show a ruptured HOC with pelvic free fluid on transabdominal ultrasound.

Figure 10.30 **A ruptured hemorrhagic ovarian cyst on transabdominal ultrasound.**

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Keywords/Tags: Hemorrhagic Ovarian Cysts

Learning Point 18: When a hemorrhagic cyst ruptures, echogenic fluid is seen in the pelvis or may even result in massive hemoperitoneum.

19. EXPLANATION

C. It is usually easy to differentiate fallopian tube from ovary. The image shows a TOA. The ultrasound findings of TOAs are nonspecific and variable, but multiple loculations, solid and cystic components, as well as internal septations are all common. Gas is not a usual finding in acute TOA and will be hyperechoic with air shadowing artifact. Debris, pus, or hemorrhage are common findings in TOA and typically result in low-level internal echogenicity.

Often, the fallopian tube and ovary cannot be identified as discrete entities and form a tubo-ovarian complex. Hydrosalpinx and pyosalpinx may appear early in the course of TOA development and prior to visualization of an abscess. Both will present with a hypoechoic dilated fallopian tube, but the presence of low-level echoes or debris within the tube suggests pyosalpinx. In addition, on color Doppler, TOAs will display a ring of fire sign due to the surrounding hyperemia (Figure 10.14).

CT may be considered if the ultrasound is nondiagnostic, especially if the TOA is small or in an atypical location. In addition, CT can help to diagnose less common causes of TOA, such as tuberculosis, ruptured bowel (e.g., diverticulitis), or fistula tracts from inflammatory bowel disease. However, transvaginal ultrasound should be considered first, as it can make the diagnosis, guide transvaginal drainage of the TOA, and avoid radiation and excess cost.

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Keywords/Tags: Adnexal Mass, TOA, Tubo-ovarian abscess

Learning Point 19: In TOA there is usually destruction of normal ovarian structures and formation of complex adnexal mass.

20. EXPLANATION

B. It is noninvasive. Transabdominal ultrasound is preferred in younger patients as it is less invasive and they often have a body habitus more amenable to visualizing pelvic organs and pathology transabdominally. This approach should be the first choice for visualizing uterine pathology, pelvic free fluid, and assessing intrauterine pregnancy.

Transvaginal ultrasound provides better visualization of the adnexa and ovaries and is the test of choice for TOAs, ovarian torsion, and ovarian cysts. It may also provide clearer images of uterine pathology or early pregnancy depending on body habitus. Transvaginal ultrasound has the disadvantages of being invasive and time consuming and should be avoided whenever possible in young patients who have never been sexually active.

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Keywords/Tags: Transvaginal Ultrasound, Transabdominal Ultrasound of the Pelvis

Learning Point 20: Advantages of transabdominal ultrasound are that it is fast and noninvasive. Advantages of transvaginal ultrasound are that it can provide more detailed evaluation of pelvic organs, especially the ovaries and adnexa.

21. EXPLANATION

D. 26 or more follicles on at least 1 ovary. Although the exact cause of PCOS remains unclear, hyperandrogenism, menstrual abnormalities, and polycystic ovaries are cardinal features. Treatment is aimed at controlling androgen levels, often pharmacologically with estrogen-progesterone oral contraceptives. Diagnosis is multifaceted and requires hormonal testing; however, ovaries with greater than or equal to 26 follicles are associated with a specificity of 94% and sensitivity of 85% for PCOS (Figure 10.31). This is increased from the prior cut-off of 12 follicles or more on a single ovary, as the prior cut-off led to overdiagnosis of PCOS in women with normal menstrual cycles. Transabdominal pelvic ultrasound should not be used to assess for the number of follicles, as image quality is often too poor to obtain an accurate follicle count.

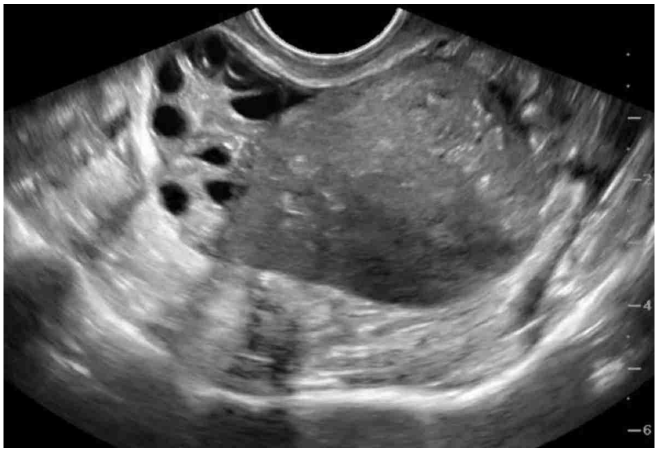

Figure 10.31 **Polycystic ovary seen on transvaginal ultrasound.** Note that transvaginal ultrasound should be performed to make the diagnosis, and polycystic ovaries should contain ≥26 follicles. Slowly fanning through the ovary will facilitate counting the number of follicles.

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Keywords/Tags: Polycystic Ovarian Syndrome

Learning Point 21: Ultrasound can be used to aid diagnosis of PCOS if many follicles are visualized.

22. EXPLANATION

A. Teratoma. These are germ cell tumors that have more than one cell type, with immature types more likely to be

malignant. Mature cystic teratomas are called dermoid cysts. However, the terms "teratoma" and "dermoid cyst" are often used interchangeably. On ultrasound (Figure 10.32), they have a highly variable appearance but usually have a cystic component (C), bright hyperechoic areas with shadowing that can be consistent with bone or teeth (A), and/or fat-fluid (B) levels. The appearance of teratomas can be similar to other ovarian neoplasms, including ovarian carcinoma, and the two cannot be differentiated with bedside ultrasound. One of the most clinically important features of teratomas and dermoid cysts is their propensity to cause ovarian torsion. Ultrasound findings consistent with cystic teratoma in patients with suspected ovarian torsion was associated with an odds ratio of 7.8 in a recent study.

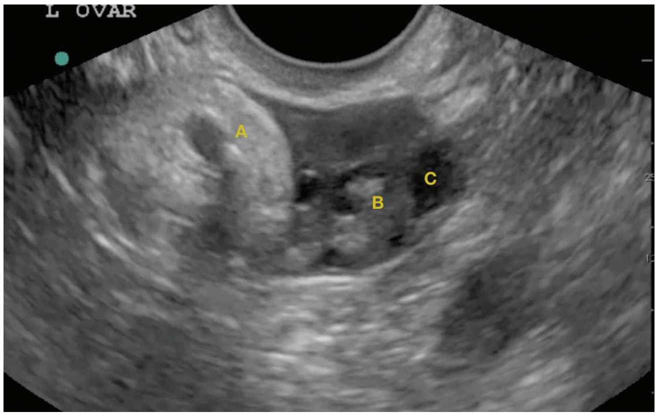

Figure 10.32 **Cystic teratoma on transvaginal ultrasound.** Note the solid component with shadowing artifact (a), which is likely a tooth or bone. Also note the fat component (b), as well as the fluid component (c).

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Keywords/Tags: Teratoma

Learning Point 22: Teratomas have a highly variable appearance that can overlap with the appearance of other ovarian neoplasms. They are associated with ovarian torsion.

23. EXPLANATION

B. At least stage 2. While gynecological oncologists should be consulted to provide follow-up and management of patients with high concern for ovarian cancer, POCUS clinicians are often expected to provide patient counseling, as the diagnosis is often first made in EDs and clinics.

The FIGO staging system is used to stage ovarian cancer using the criteria listed in Table 10.3. Further characterization within each stage is made using the TNM staging system. Recent literature estimates stage related survival at 10 years for stages I, II, III, and IV at 3% to 92%, 45% to 55%, 21%, and <6%, respectively. Initial treatment of ovarian cancer consists of surgical resection if possible and platinum based chemotherapy, with some cancers being amenable to newer medications directed at specific molecular targets.

Table 10.3. **FEDERATION OF GYNECOLOGY AND OBSTETRICS CLASSIFICATION FOR OVARIAN CANCER**

Stage 1	Tumor isolated to ovary(s) or fallopian tube(s)
Stage 2	Tumor of at least one ovary/fallopian tube with extension to peritoneum or pelvic organs or tissue below pelvic brim
Stage 3	Tumor involves at least one ovary or fallopian tube or peritoneum, and has spread to either retroperitoneal lymph nodes or the peritoneum outside the pelvis
Stage 4	Metastasis to distant tissue excluding the peritoneum

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Keywords/Tags: Ovarian Cancer

Learning Point 23: The FIGO staging system is used to describe extent of ovarian cancer based on organs or abdominal structures involved.

24. EXPLANATION

C. Right upper quadrant (Morrison's pouch). The patient's presentation is concerning for hypovolemic shock given the amount of free fluid on pelvic ultrasound. Potential causes could include large ruptured hemorrhagic cyst, perforated viscus, or ruptured ectopic pregnancy. Initial evaluation with transabdominal pelvic ultrasound is appropriate given the patient's symptoms and vital signs. The ultrasound image shows fluid in the posterior cul-de-sac (pouch

of Douglas) as well as the anterior cul-de-sac concerning for massive hemoperitoneum. Visualization of fluid in the right upper quadrant would suggest significant intra-abdominal bleeding. Transvaginal ultrasound of the pouch of Douglas would be unlikely to reveal additional information, as fluid is seen there on transabdominal ultrasound. Pulmonary imaging is not indicated given the patient's symptoms and atraumatic history. Intra-abdominal free fluid is more likely to be visualized in the right upper quadrant (Figure 10.13b) before the left upper quadrant.

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Keywords/Tags: Abdominal Free Fluid, Pouch of Douglas, Morison's Pouch

Learning Point 24: The anterior cul-de-sac is bounded by the bladder anteriorly and the uterus posteriorly. This is not a dependent potential space, and normally there is no free fluid seen here.

25. EXPLANATION

C. Hemorrhagic ovarian cyst. The image is most consistent with a hemorrhagic cyst. Hemorrhagic cysts have fine thin internal echoes or may show frank clot. Otherwise their appearance is similar to simple cysts with thin walls, posterior acoustic enhancement, and no internal vascularity. They are often seen when bleeding occurs within simple/follicular cysts but are abnormal in patients who are postmenopausal. In fact, any ovarian cyst ≥1 cm in a postmenopausal patient should warrant close follow-up. Corpus luteum cysts are thick walled with peripheral vascularity and form after ovulation. They are also not seen in patients who have been postmenopausal for many years. While there are similarities, this image shows the classic lace-like, reticular pattern of HOC, while PCOS consists of multiple follicles.

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Keywords/Tags: Hemorrhagic Ovarian Cyst, Corpus Luteal Cyst, Pelvic Pain

Learning Point 25: Hemorrhagic cysts are abnormal in postmenopausal women and are concerning for possible malignancy.

26. EXPLANATION

D. All of the above. This patient has an endometrioma on transvaginal ultrasound. This estrogen-dependent cyst resembles a hemorrhagic ovarian cyst, but it has a more homogenous appearance to its internal echoes. In Figure 10.19a, note the homogenous "ground glass" echogenic texture in the cyst. Endometriomas are seen in up to 20% of women, with about 25% occurring bilaterally. Her recurrent pelvic pain and pleuritic chest pain associated with her menstrual cycle highly suggests endometriosis with distal involvement as the cause of her symptoms.

Endometriosis is characterized by the spread of endometrial tissue outside of the uterus. The mechanism(s) of spread are unknown but can be from metaplasia, lymphatic spread, or direct implantation from ectopic endometrium that travel in "retrograde menstruation" from the fallopian tubes to the peritoneum. Sites for spread of endometriosis are commonly retroperitoneal or peritoneal but less commonly involve the pulmonary system or the central nervous system. In Figure 10.19b, note the presence of the vertebral column above the diaphragm (spine sign), indicating an effusion from endometrial tissue invading the pleura. The fibrin strands from the hemothorax are also visualized. Pulmonary involvement in endometriosis is rare but may be associated with pulmonary cysts, hemothorax, and pneumothorax. A laparoscopic evaluation is the gold standard, as it will confirm the diagnosis as well as allow for surgical management. NSAIDs and oral contraceptives may be considered for less severe presentations.

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Keywords/Tags: Endometriosis

Learning Point 26: Endometriosis is characterized by endometrial tissue that has migrated outside of the uterus. It is a common cause of dysmenorrhea, dyspareunia, and chronic pain and is associated with infertility. Endometriomas are cysts with homogenous "ground glass" internal echoes.

27. EXPLANATION

D. All of the above. Adenomyosis is the invasion of endometrial cells into the myometrium of the uterus. It is relatively common, as up to 30% of women are affected, usually with symptoms appearing in the fourth decade. In the follicular phase, these ectopic endometrial cells cause swelling to the myometrium, therefore leading to increased cyclical pelvic pain and menorrhagia. Treatment can be hormonal-based IUD or surgical resection.

Diagnosis on ultrasound can be difficult due to the highly variable appearance and some similarities to leiomyomas. Findings include (see Figure 10.33):

- A globular enlarged uterus.
- Heterogeneous myometrial echogenicity.
- Indistinct endometrial-myometrial borders.
- Linear striations in the myometrium.
- Myometrial cysts.
- Asymmetric thickening of the myometrium.

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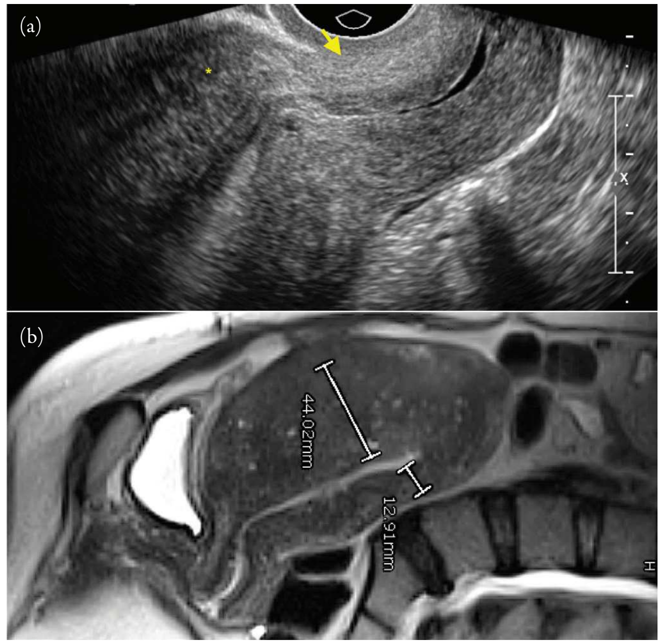

Figure 10.33 (a) **Adenomyosis on transvaginal ultrasound.** Note the enlarged uterus, asymmetric thickening (*) and heterogeneous appearance (arrow) of the anterior myometrium. *Image courtesy of Shaden Mohammad, MD, and Monica Deshmukh, MD, Department of Radiology, Olive View–UCLA Medical Center, Los Angeles, CA.* (b) **Adenomyosis on T2-weighted magnetic resonance imaging of the pelvis.** On this long axis view of the uterus, note the asymmetric thickening of the anterior myometrium, as well as the micro-cysts and heterogeneous signals from the myometrium.

Keywords/Tags: Adenomysosis

Learning Point 27: Adenomyosis is invasion of endometrial tissue into the myometrium. It is a common cause of recurrent pelvic pain and menorrhagia. On ultrasound, there is a heterogeneous appearance to the echogenicity of the myometrium as well as an indistinct endometrial-myometrial border.

11.

SOFT TISSUE ULTRASOUND

Yiju Teresa Liu, Lilly Bellman, Jackie Shibata, and Sheetal Khiyani

QUESTIONS

1. A 7-year-old boy presents 2 days after falling in the woods and getting several splinters in his hand. His parents removed the easily visible ones but he still feels like there is something in the palm of his hand. On your initial exam with a high-frequency linear probe, you do not see any foreign bodies. He is also squirming. What adjunct could help you better see a very superficial foreign body and also make the scan less painful?

A. Have someone help hold the boy's hand down.
B. Use a standoff pad.
C. Change to a curvilinear probe.
D. Get an X-ray instead.

2. A 32-year-old female presents with pain and swelling in her left axilla. You are concerned for abscess but know this is an area with large vascular structures. On ultrasound you see the image shown in Figure 11.1.

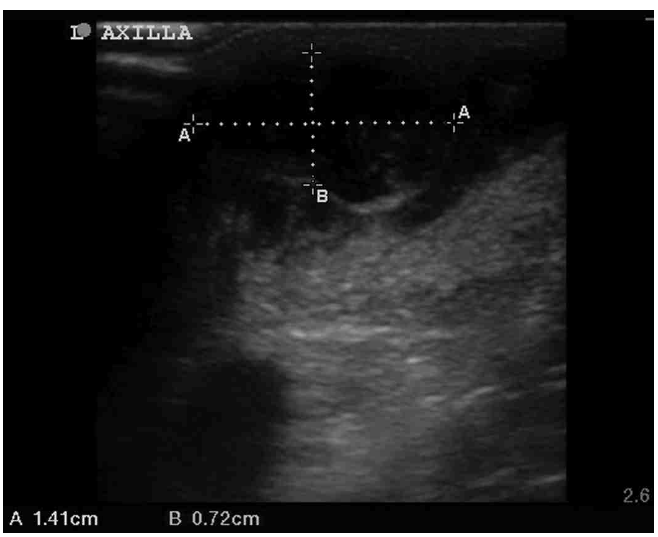

Figure 11.1

Before you prepare for incision and drainage, how can you differentiate a suspected abscess from a blood vessel?

A. Apply pressure to evaluate movements of internal contents of the structure (i.e., swirl sign). If there is no movement then it demonstrates a vessel.
B. Apply pressure to evaluate collapsibility of the structure. Any degree of collapsibility suggests a venous structure.
C. Apply Doppler. Seeing central flow suggests hyperemia and therefore infected tissue.
D. Apply Doppler. No flow suggests that the structure is not vascular.

3. A 50-year-old male is transferred from an outside emergency department (ED) after blunt chest trauma. He has right lateral chest pain that he describes as mild and tingling. His vitals are temperature 37.3°, heart rate 78, respiratory rate 16, SpO_2 98% on room air. You evaluate his chest wall with ultrasound and see the image in Figure 11.2.

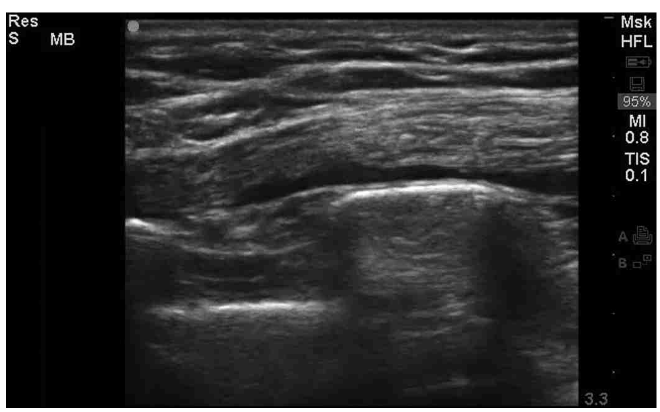

Figure 11.2

Where is fluid visible in this image?

A. Subcutaneous tissue
B. Fascial plane
C. Intramuscular
D. No fluid

4. A 28-year-old otherwise healthy construction worker presents with 2 days of progressive, intense pain in his left calf and fever. He thinks maybe he stubbed his toe the other day but otherwise denies injury. His vital signs include heart rate 110, temperature 38.5°, respiratory rate 14, SpO_2 99%. On exam, his left calf is erythematous and edematous and is intensely tender to palpation. On ultrasound, you see the images in Figure 11.3 and Video 11.1.

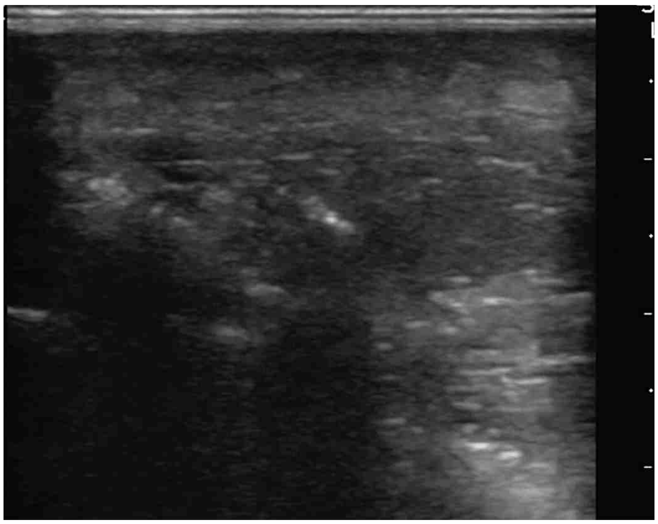

Figure 11.3

What are your next clinical steps in caring for this patient?

A. Discharge home with oral antibiotics; the findings are consistent with local cellulitis.
B. Give an intravenous (IV) dose of antibiotics, draw labs (complete blood count [CBC], C-reactive protein [CRP], blood culture, lactate, creatine kinase [CK]) and arrange admission to the hospital for IV antibiotics for cellulitis.
C. Draw labs (CBC, CRP, lactate, blood culture, CK), begin fluid resuscitation; give a dose of IV broad-spectrum antibiotics, and notify surgery because you are concerned for necrotizing fasciitis.
D. Call surgery to make a follow-up appointment tomorrow.

5. A patient comes to the ED after recent removal of a dialysis permacatheter. She is complaining of pain and swelling to her right groin where the catheter was. You place a probe over the area and see the image in Figure 11.4 and Video 11.2.

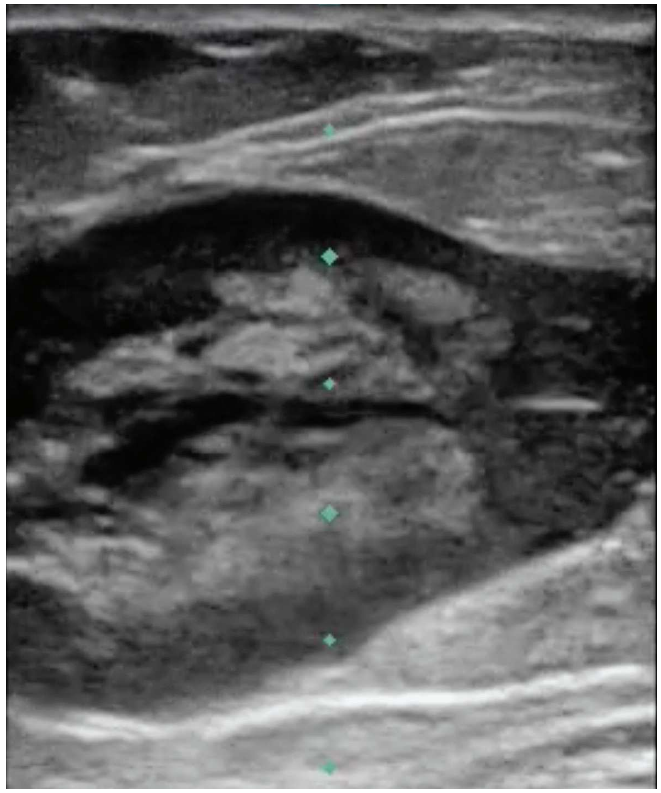

Figure 11.4

Which of the following diagnoses is most likely?

A. Hematoma
B. Reactive lymph node
C. Deep vein thrombosis (DVT)
D. Pseudoaneurysm

6. A 6-year-old girl is brought in with a swollen, painful area over her left calf. She states she was bitten by something 3 days ago. Since yesterday, the redness has rapidly spread, and the area has become more painful. She began having subjective fever as well. Her vitals are temperature 37.8°, heart rate 96, respiratory rate 18, SpO_2 100% on room air. On exam, her left calf has an approximately 8 × 10cm area of warmth, erythema, and induration without clear fluctuance, with a small punctum in the center.

Ultrasound imaging with a linear probe of both the affected leg and the unaffected leg is shown in Figure 11.5.

What does this finding suggest?

A. Peripheral edema
B. Cellulitis
C. Foreign bodies
D. Multiple lymph nodes

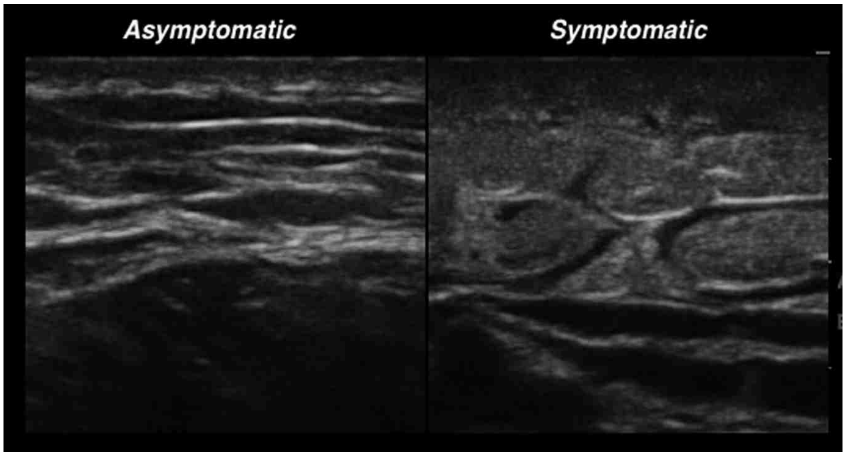

Figure 11.5

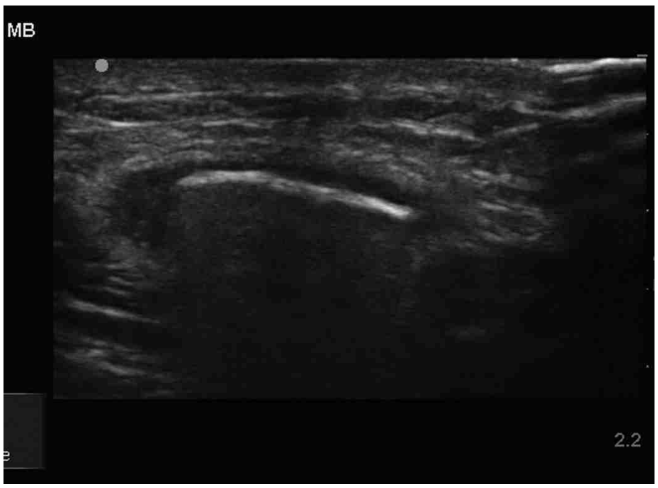

Figure 11.6

7. A man comes to the ED a week after he kicked a glass door; he has pain in his foot and is unsure if he has glass inside. What would you expect to see on ultrasound for suspected foreign body?

A. A hyperechoic structure
B. Halo sign
C. Artifact
D. All of the above

8. A 25-year-old gardener was working with mulch and got several splinters in his hands. He was able to remove some splinters himself but comes into the ED with a foreign body sensation in his right hand. What is the best first step to image his hand to evaluate for foreign body?

A. Computed tomography (CT) scan
B. Ultrasound
C. X-ray and ultrasound together
D. X-ray alone

9. All of the following are best practices for soft tissue ultrasound *except*:

A. Scan areas or objects of interest in at least 2 orthogonal planes.
B. Use a low-frequency probe to best image superficial structures.
C. Use a high-frequency probe to best image superficial structures.
D. Use dual mode to compare findings from asymptomatic and symptomatic areas.

10. A 32-year-old male is being evaluated after a dirt bike accident where he fell into woodchips. He has many splinters and a large undermined laceration and abrasion over his right forearm. You notice gravel and wood chips in the wound. After numbing his wound and removing the visible foreign bodies, you use the ultrasound to explore skin over an undermined area of wound and see the image in Figure 11.7.

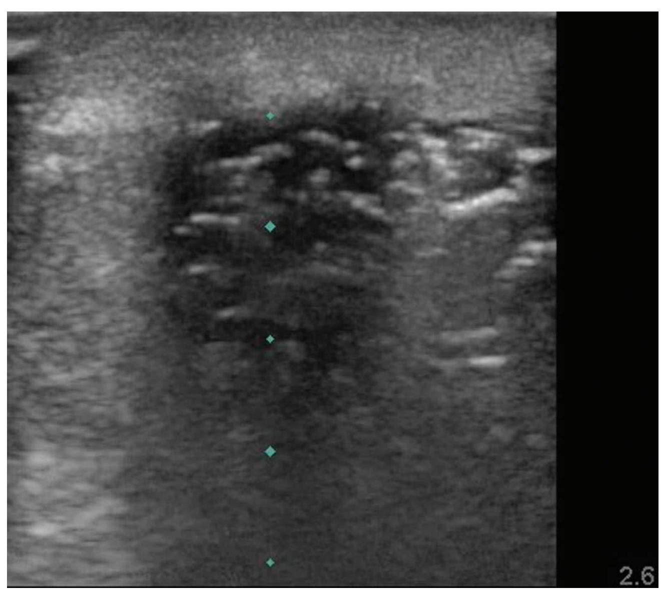

Figure 11.7

How do you interpret this ultrasound evaluating for foreign bodies?

A. Multiple hyperechoic foreign bodies visualized consistent with gravel
B. Multiple hyperechoic foreign bodies visualized consistent with wood splinters
C. No foreign body visualized. No need for further imaging because ultrasound is the best study for this indication.
D. This study is limited by air in the wound and cannot rule out retained foreign body.

11. A 27-year-old woman presents with a red, painful area on her left calf that has rapidly increased in size since yesterday over an area where she believes she may have been bitten by a mosquito. On exam, there is an 8 × 10 cm tender, erythematous, indurated area without fluctuance. What are the best next steps?

A. Give a trial diphenhydramine for presumed allergic reaction to the mosquito bite and then reassess for response. If no improvement, treat for cellulitis.
B. Numb the area with lidocaine and attempt to aspirate the area with an 18-gauge needle because the area seems concerning for a drainable collection.
C. Prescribe empiric antibiotics to cover strep and staph for uncomplicated cellulitis.
D. Use ultrasound to evaluate for a fluid collection. If there is a collection, prepare for a drainage procedure and consider antibiotics as well; if no fluid or only a very small <0.5 mm collection is identified, treat empirically for cellulitis.

12. A 38-year-old woman feels a lump in her right breast that is nontender. She has no lymphadenopathy, skin, or nipple changes. There is a soft, mobile mass at about 9 o'clock. With ultrasound, you scan in 2 orthogonal planes and see a 5 mm mass below (Figure 11.8).

Figure 11.8

What is the likely diagnosis?

A. Breast abscess
B. Simple cyst
C. Complex cyst
D. Malignancy

13. A homeless 45-year-old male presents with foot pain. He is barefoot. He says, "Something is inside my foot." After cleaning the affected region, you perform an ultrasound and see the image in Figure 11.9.

Figure 11.9

What technique can help separate the foreign body from the surrounding tissue and aid removal?

A. Hydrolocation
B. Hydrodissection
C. Guidewire placement
D. X-ray

14. A patient noticed a lump in his neck and is concerned about cancer. You palpate a tender mass; the bedside ultrasound is shown in Figure 11.10.

Which of the following statements regarding both benign and reactive lymph nodes (as opposed to malignant lymph nodes) is true?

A. Normal lymph nodes are circular.
B. Normal lymph nodes are mostly hypoechoic.
C. Normal lymph nodes have an echogenic center.
D. Normal lymph nodes have predominantly peripheral vascularity seen with color Doppler.

15. A 40-year-old woman presents with a mass on her neck for the past several months. She decided to come to seek medical care when it became more painful this week. She denies any trauma or anticoagulation. On exam, there

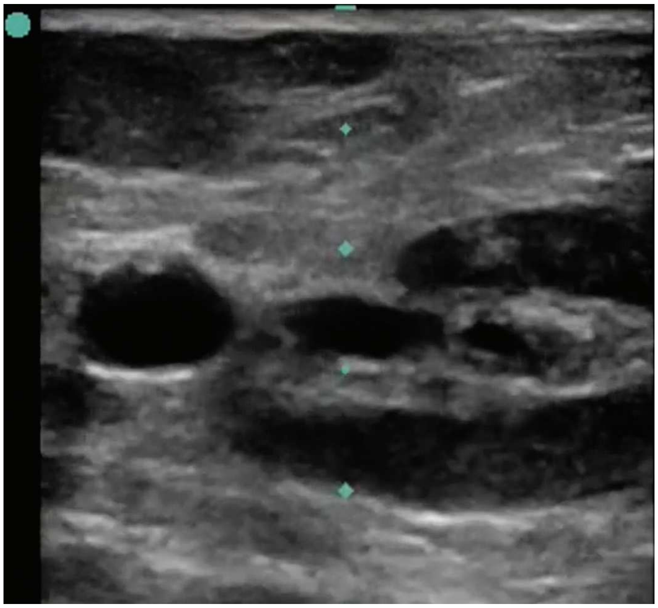

Figure 11.10

16. A 70-year-old woman with a history of diabetes presents with a nodular mass on her palm for the past several months. She has noticed that it is more difficult to extend her ring finger. You suspect Dupuytren's disease and perform an ultrasound, seen in Figure 11.12.

What do you expect to see?

A. Solid mass with a heterogeneous echo pattern and blood flow
B. Well-defined homogenous hyperechoic mass
C. Hypoechoic lesion with irregular margins
D. Solid hypoechoic mass broadly attached to the fascia

17. A 30-year-old female presents with irritation to the site where she had a thyroidectomy about 1 year ago. The incision site looks well healed, and no masses are palpated. However, when you touch her neck at a certain is a fixed nodular mass in her anterior-lateral neck that is about 3 cm in diameter. Her ultrasound is shown in Figure 11.11a and Figure 11.11b and Video 11.3.

What is the most likely diagnosis?

A. Necrotizing fasciitis
B. Malignant tumor
C. Abscess
D. Hematoma
E. Epidermoid cyst

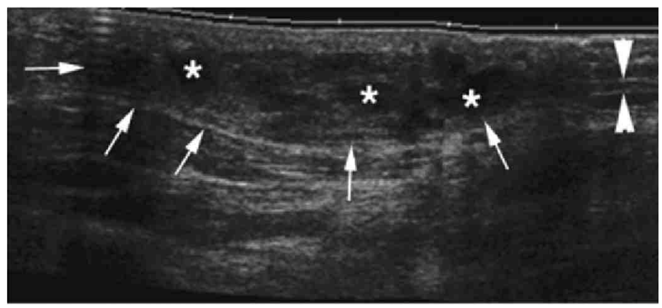

Figure 11.12 Adapted from Figure 7.49B of O'Connor PJ. Investigating foot and ankle problems. In: Conaghan PG, O'Connor P, Isenberg DA, eds. *Musculoskeletal Imaging*. New York, NY: Oxford University Press; 2010.

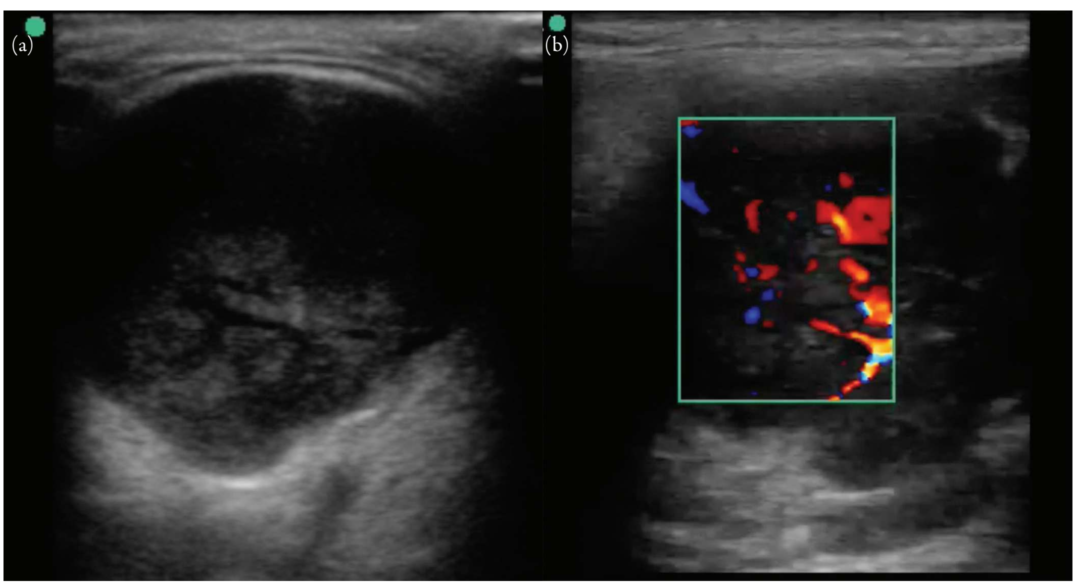

Figure 11.11

point, she says she "feels something there." You perform an ultrasound and see the image in Figure 11.13.**

Figure 11.13 From Figure 1 of Kobaly K, Mandel SJ, Langer JE. *J Clin Endocrinol Metab*. 2015;100(2):371–375.

What is the likely diagnosis?

A. Abscess
B. Hematoma
C. Suture granuloma
D. Recurrent tumor

18. A man with a history of DVT on coumadin presents to the ED with ecchymosis to his abdominal wall after a mechanical fall. You do an ultrasound and find the image in Figure 11.14.

Which of the following most likely?

A. This is not a hematoma because it has internal echoes.
B. This is most likely an abscess because it has internal echoes.
C. This is most likely a hematoma because he has no infectious symptoms, and he is on anticoagulation and status posttrauma.
D. This is most likely a sarcoma.

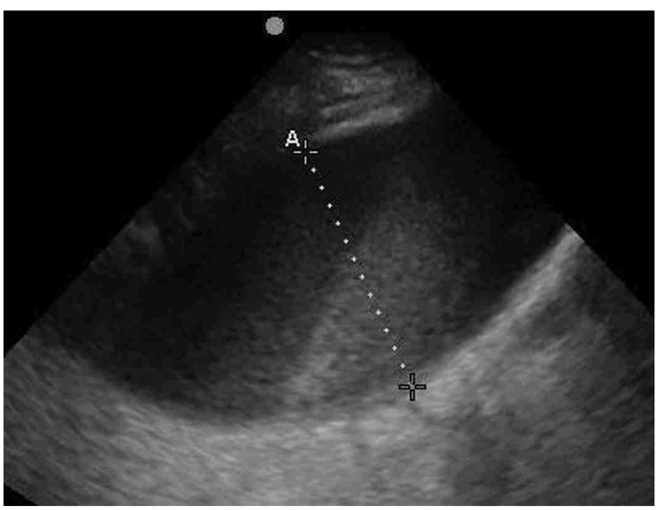

Figure 11.14

19. A 40-year-old man complains of a small lump he feels on his left cheek that he notices when he washes his face. It has been there for months and is nonpainful. It has not recently changed in size. On exam, you note a non-tender, smooth, ~0.5 × 1 cm mass that is very superficial. You suspect an epidermoid cyst based on physical exam. What sonographic findings would support this diagnosis?

A. A round, well-circumscribed, anechoic mass with posterior acoustic enhancement in the subcutaneous layer
B. An ill-defined heterogeneous mass with increased color Doppler signal compared to surrounding tissue that crosses tissue lines
C. An ovoid, heterogeneous, hypoechoic mass with hyperechoic swirls and posterior acoustic enhancement in the dermal layer with a tract leading to the skin surface
D. An ovoid, isoechoic mass with hyperechoic curved linear lines in the subcutaneous fat layer

20. You want to use ultrasound to guide an incision and drainage procedure for an abscess. You are worried about infection control. All of the following are simple ways to protect the patient and the probe *except*:

A. Use alcohol wipes to clean the probe.
B. Apply a Tegaderm© to the probe.
C. Use a sterile probe cover.
D. Use a glove to cover the probe.

21. You are attempting to perform a median nerve block and place a linear probe on your patient's forearm. Which of the following correctly identifies each structure labeled in the image in Figure 11.15?

A. 1: Gel pad; 2: Epidermis; 3: Dermis; Blue Circle: Vascular Structure; Red Circle: Tendon; Yellow Circle: Bone; 4: Median Nerve; 5: Muscle
B. 1: Gel pad; 2: Dermis; 3: Epidermis; Blue Circle: Tendon; Red Circle: Vascular structure; Yellow Circle: Median Nerve; 4: Bone; 5: Fat
C. 1. Gel pad; 2: Epidermis; 3: Dermis; Blue Circle: Median Nerve; Red Circle: Vascular Structure; Yellow Circle: Muscle; 4: Bone; 5: Tendon
D. 1: Gel pad; 2: Epidermis; 3: Dermis; Blue Circle: Tendon; Red Circle: Vascular Structure; Yellow Circle: Median Nerve; 4: Bone; 5: Muscle

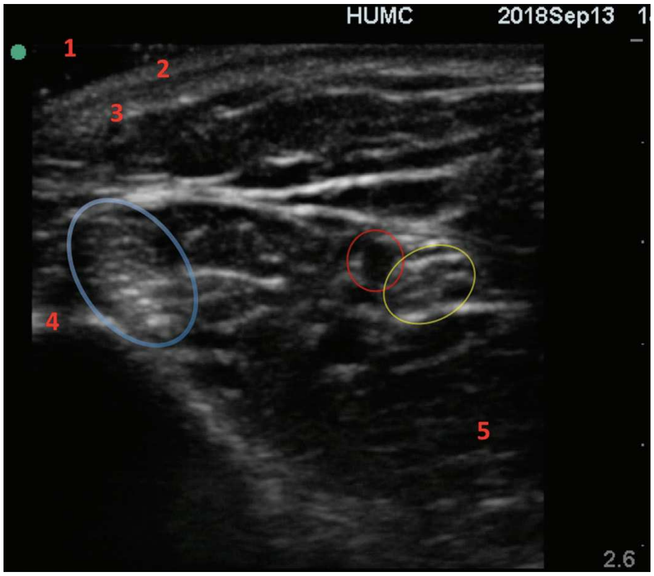

Figure 11.15

22. A 50-year-old man complains of a lump over his abdomen. On your exam, it is soft, mobile, and non-tender and is approximately 2 × 4 cm. On ultrasound with a linear probe, you see the images in Figure 11.16 and Video 11.4.

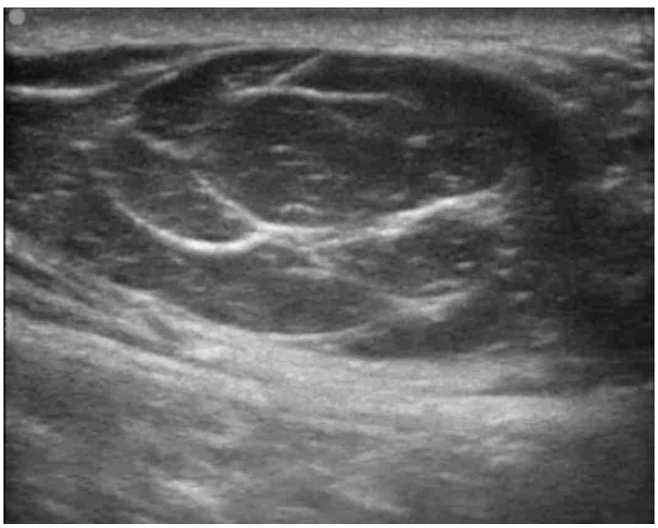

Figure 11.16

What is the most likely diagnosis?

A. Lipoma
B. Reactive lymph node
C. Epidermoid cyst
D. Abscess

23. A man complains of swelling in his groin after moving heavy furniture. Which of the following is true when evaluating for an inguinal hernia?

A. The patient should be placed in Trendelenberg.
B. The patient should Valsalva while the probe is placed over the lower abdomen parallel to the inguinal canal with inferior epigastric vessels located laterally.
C. Inguinal hernias are more easily visualized when the patient is supine as opposed to standing.
D. A hernia that includes bowel will always have peristalsis as it does in the abdomen.

24. A patient presents after a stab wound to the chest with pain and shortness of breath. You quickly grab the ultrasound to perform an Extended Focused Assessment with Sonography in Trauma (E-FAST) and obtain the images in Figure 11.17 and Video 11.5. Which of the following is the correct ultrasound interpretation?

A. There is no lung sliding so the patient has a pneumothorax.
B. There are B-lines, so the patient does not have a pneumothorax.
C. There is subcutaneous air, which obscures evaluation of pneumothorax.
D. The patient has pulmonary edema causing his symptoms.

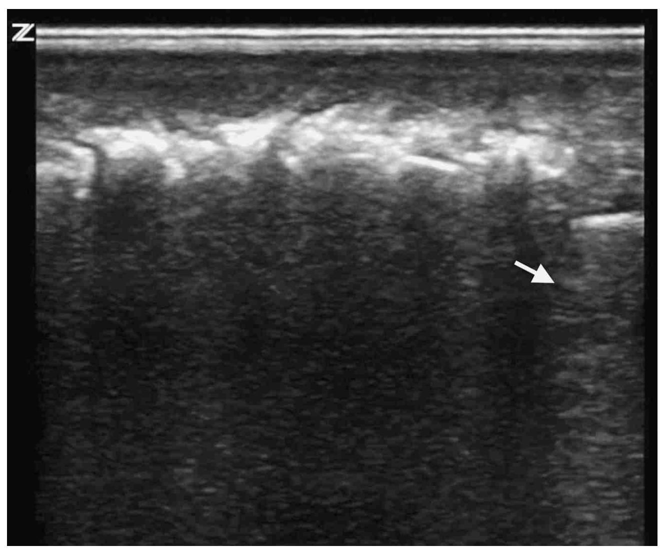

Figure 11.17

ANSWERS

1. EXPLANATION

B. Use a standoff pad. Organic foreign bodies such as wood splinters are not seen on plain film radiography but can be identified on ultrasound. However, it can be difficult to image very superficial structures including tendons, superficial vessels, as well as foreign bodies. Commercially produced standoff pads come in multiple shapes, sizes, and materials (generally, they consist of a gel-filled pad that can be used instead of ultrasound gel). These offer a movable acoustic window to more easily visualize very superficial structures. An IV bag or glove filled with water can provide a similar function (Figure 11.18). They can also help make a scan less painful by decreasing the amount of direct pressure on the scanning area. Other helpful methods include imaging in a water bath or being very generous with ultrasound gel (Figure 11.18). Having a helper position this patient can also be somewhat helpful but will not improve visualization of very superficial structures. A curvilinear probe would be best for deeper structures. A hockey stick probe, if available, can be helpful. In other cases, an endocavitary probe can help when trying to image a concave area (i.e., a webspace).

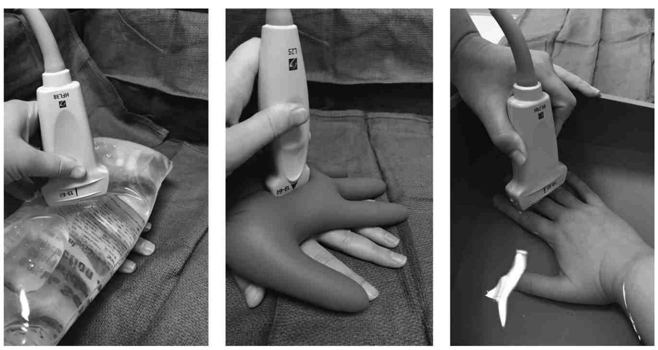

Figure 11.18 **Imaging adjuncts for ultrasound.** When imaging an irregular structure like fingers or a part of the body that may be sensitive to pressure, imaging adjuncts can be used. These provide a good interface for ultrasound waves to be transmitted while minimizing pressure to the tissue. From left to right: an IV bag, a glove filled with water, and a water bath. Note that in a water bath, the transducer does not have to be in contact with the tissue. A commercial gel block or standoff pad (not pictured) can also be used.

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Keywords/Tags: Superficial structure, foreign body, adjunct equipment, acquisition, image enhancement

Learning Point 1: Adjuncts like a standoff pad (which can be imitated by filling a glove with water) or imaging in a water bath can help better visualize very superficial structures/objects as well as minimize pain when scanning over a tender area.

2. EXPLANATION

D. Apply Doppler. No flow suggests that the structure is not vascular. Interrogating hypoechoic structures in question with Doppler (color or spectral) can help determine if a structure is vascular or not. In an abscess, we expect no flow. Vessels would have blue or red flow depending on the movement of blood to or away from the probe (remember BART—Blue Away and Red Toward). Of note, the periphery of an abscess (not the center) may be hyperemic with increased signal on Doppler examination (Figure 11.19a). Applying pressure to a suspected abscess and noting movement of internal contents (sometimes called the "swirl sign") can be helpful as well (Video 11.6). Abscesses can be variable in terms of how compressible they may be (Figure 11.19b). Veins typically will compress with pressure while arteries are less compressible, have thicker walls, and are pulsatile.

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Keywords/Tags: Aquisition, doppler, soft tissue, image interpretation

Learning Point 2: Color Doppler can help distinguish an abscess from a vascular structure.

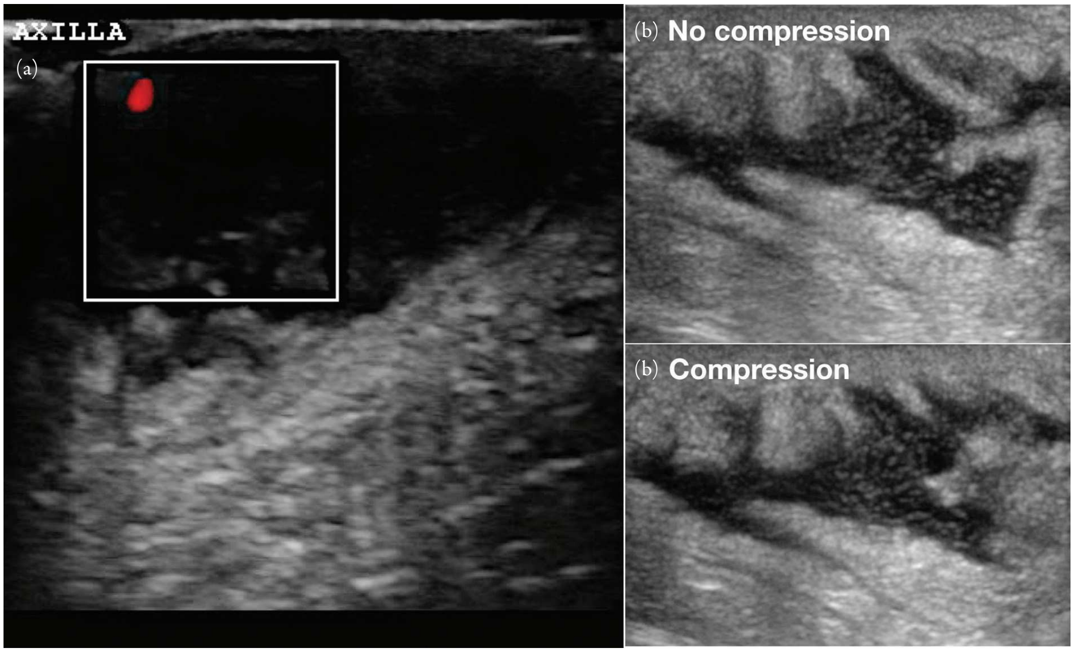

Figure 11.19 (a) **Abscess with peripheral flow.** Color Doppler interrogation of the more superficial hypoechoic area indicates minimal color flow (the small area creating signal is near the periphery of the fluid collection). This could be sign of peripheral hyperemia, which can be seen in an abscess. (b) **The swirl sign.** There is movement of echogenic debris without and with compression. The mobile debris implies purulent fluid that can be drained and may help to distinguish a true abscess versus a phlegmon that cannot be drained.

3. EXPLANATION

B. Fascial plane. This image shows a layer of fluid located in a fascial plane, in this case in the posterior plane of the serratus muscle. This fascial plane fluid was created by a serratus anterior block, which may have been performed at the referring institution for pain control in the setting of rib fractures. The serratus anterior block is performed over the lateral chest wall between the third and fourth intercostal spaces (Figure 11.20a). Local anesthetic is deposited just anterior to the serratus muscle and deep to the latissimus dorsi (Figure 11.20b). The anesthetic diffuses to the T2–T9 dermatomes, thus providing pain relief to most rib fractures. Of note, a different method involves injecting anesthetic deep to the serratus muscle. However, there is a higher theoretical risk of pneumothorax with no difference in pain outcomes compared to injection anterior to the serratus muscle. No fluid is seen in the other tissue layers.

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Keywords/Tags: Sonographic anatomy

Learning Point 3: Identify and locate fluid in an ultrasound image.

4. EXPLANATION

C. Draw labs (CBC, CRP, lactate, blood culture, CK), begin fluid resuscitation, give a dose of IV broad-spectrum antibiotics, and notify surgery because you are concerned for necrotizing fasciitis. This image (Figure 11.21a and 11.21b, Video 11.7) shows a thick layer of prefascial fluid as well as gas shadowing and therefore is concerning for necrotizing fasciitis, which is a deep tissue infection that is rapidly progressive and requires prompt surgical intervention. Of note, causative agents like *Staph* or *Group A Strep* are not associated with tissue emphysema, so air artifact may not be seen. It is important to rapidly identify suspected cases because necrotizing fasciitis has high morbidity and mortality rates. One needs a high clinical suspicion to quickly identify this condition, and ultrasound is a helpful tool in its evaluation.

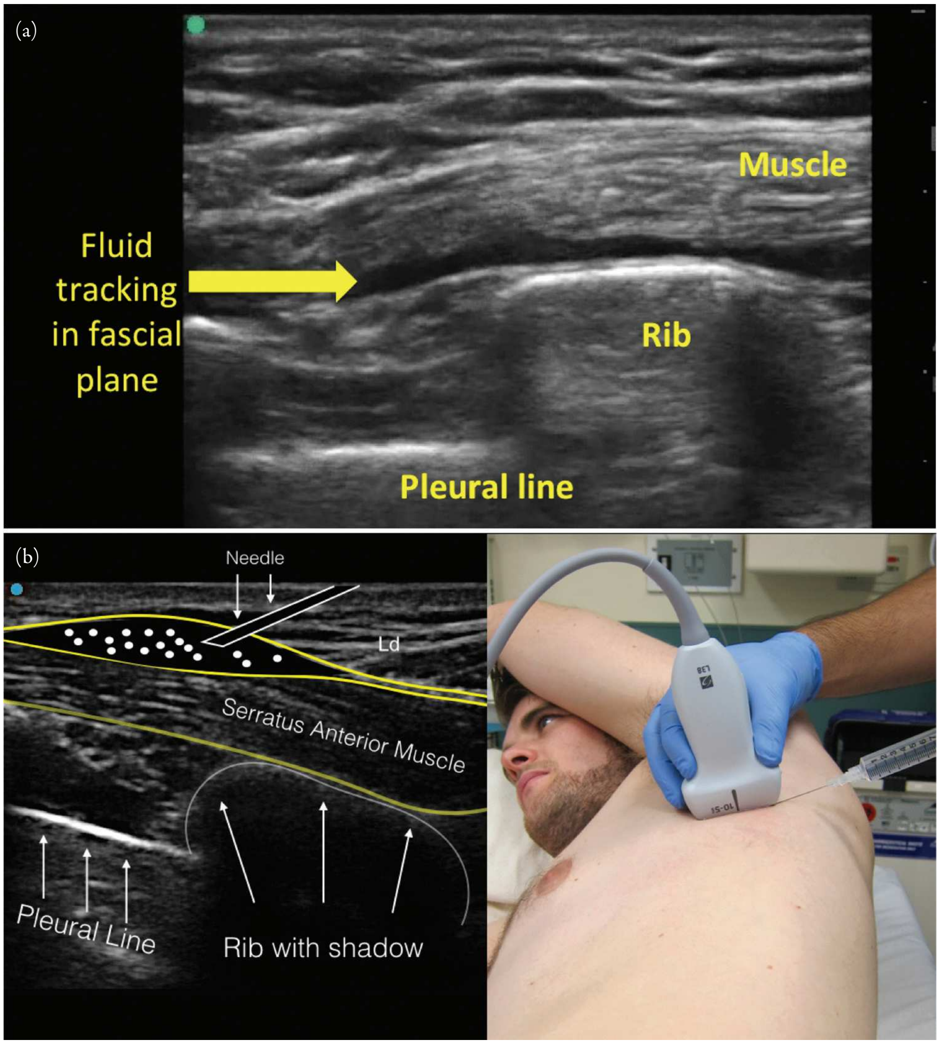

Figure 11.20 (a) **Fluid in fascial plane after serratus anterior block.** A fluid layer is seen tracking below the muscle layer after an anterior serratus block. Note that there are 2 discrete muscle bellies in the intercostal space. The more superficial is the serratus anterior, while below that are the intercostal muscles. Deep to that is the pleural lining. (b) **Serratus anterior block.** The transducer is place on the anterior to mid-axillary line at the 3rd or 4th intercostal space. The clinician must note the superficial lattisimus dorsi (Ld) muscle and the deeper serratus anterior muscle. A needle is inserted in-plane between the muscles and anesthetic is injected slowly to diffuse in the fascial plane.

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Keywords/Tags: Clinical management, image interpretation, necrotizing fasciitis

Learning Point 4: Ultrasound findings of necrotizing fasciitis include subcutaneous thickening, air artifact, fascial thickening, and fluid along fascial planes.

5. EXPLANATION

B. Reactive lymph node. A reactive lymph node has an echogenic hilum and central flow with color Doppler (Figure 11.22, Video 11.8). A hematoma will be seen in the setting of trauma and should have no vascular flow. A DVT or a vessel with a thrombus may have some peripheral blood flow but not central flow as seen in this patient. Also, a

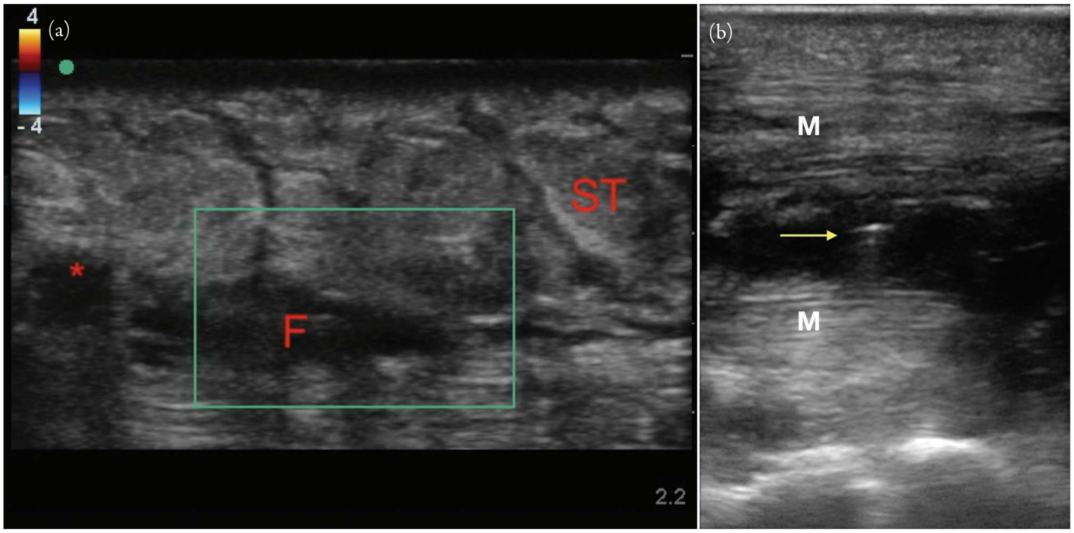

Figure 11.21 (a) **Necrotizing fasciitis.** This image shows ring down artifact from a gas bubble (*) in the subcutaneous space, as well as subcutaneous thickening (ST) with cobblestoning and fluid (F) along the fascia. (b) **Myonecrosis.** Air is seen as a distinct hyperechoic mass with ring-down artifact (arrow). It is surrounded by a collection of anechoic fluid. Note the muscle fibers (M) superficial and deep to these findings. This is a typical appearance for myonecrosis that can occur with *Clostridial* infections.

lymph node is well circumscribed and will not be visualized when translating the probe proximally or distally (unlike a blood vessel). An arterial pseudoaneurysm will have turbulent to-and-fro blood flow, often termed a "ying-yang" sign that can be seen with color Doppler.

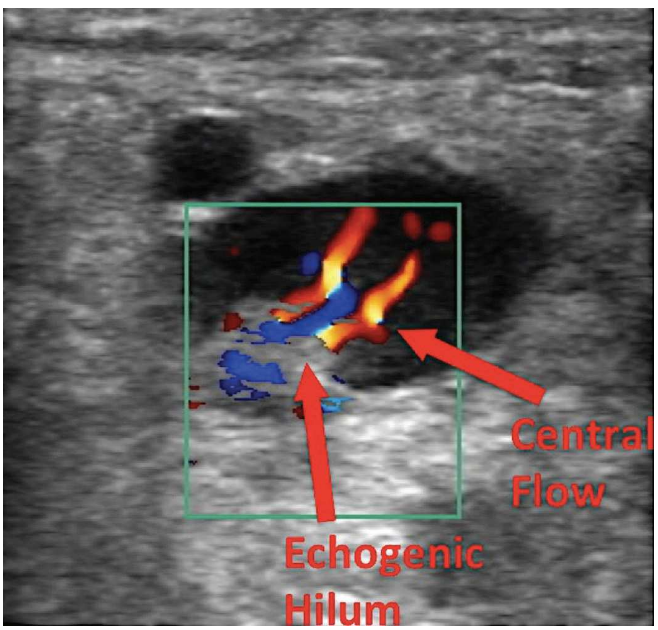

Figure 11.22 **Reactive lymph node with central flow.** On color Doppler, there is afferent and efferent flow detected in the hilum of the node.

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Keywords/Tags: Image interpretation, reactive lymph node, lymph node

Learning Point 5: Lymph nodes have a central echogenic hilum that is vascular, and their parenchyma looks very similar to that of the kidney on ultrasound. These features can help distinguish a lymph node from a hematoma or abscess.

6. EXPLANATION

B. Cellulitis. The image shows "cobblestoning," which can be seen in infection (cellulitis) or sterilely edematous tissue (such as in congestive heart failure). This characteristic appearance occurs as extracellular fluid accumulates around fat globules in subcutaneous tissue. The fluid also causes acoustic enhancement of the flat globules and deeper fascial layer, causing them to appear hyperechoic in contrast to normal tissue elsewhere. In this vignette, the unilateral nature, local pain, warmth, and subjective fever supports a diagnosis of cellulitis rather than a noninfectious cause of edema (choice A). This image is not consistent with foreign bodies or lymph nodes.

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Keywords/Tags: Image interpretation, pitfalls, limitations, cellulitis

Learning Point 6: Increased extracellular fluid (edema) between fat globules creates the appearance of "cobblestoning" in edematous or indurated subcutaneous tissue. This increased fluid also causes acoustic enhancement of the fat globules as well as the deeper fascial layer, causing them to appear hyperechoic compared to normal tissue.

7. EXPLANATION

D. All of the above. Both metallic and nonmetallic foreign bodies are hyperechoic on ultrasound (Horton 2001). While foreign body material like wood and plastic often cannot be seen on X-ray, they appear hyperechoic on ultrasound (Horton 2001). After 24 hours, the foreign body often causes a reaction, appearing as a hypoechoic halo surrounding the structure, which may result from associated hemorrhage, edema, abscess, or tissue granulation (Figure 11.23a). Foreign bodies will cause various sonographic artifacts depending on the material and size. They can cause reverberation, ring down artifact, clean shadowing, or "dirty shadowing" (Figure 11.23b).

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Keywords/Tags: Image interpretation

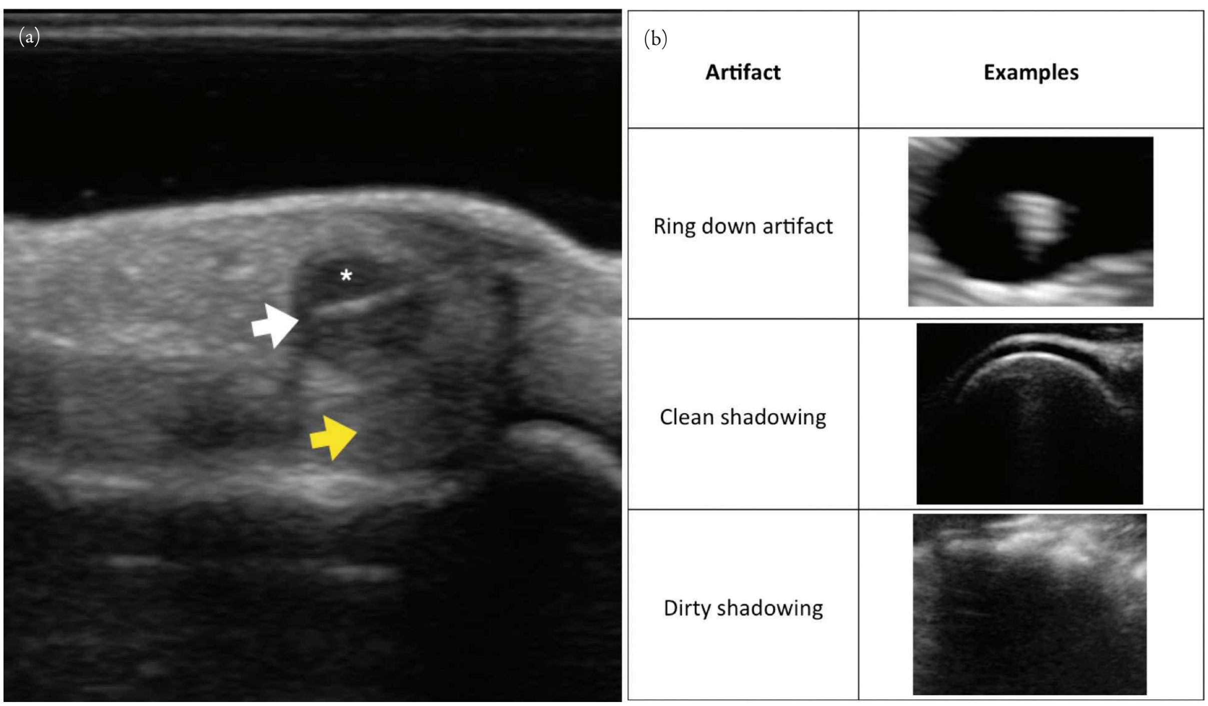

Figure 11.23 (a) **Typical appearance of foreign body on ultrasound.** This is a wood splinter lodged in the patient's finger on the palmar side. The splinter is seen as a hyperechoic linear mass (white arrow). Surrounding the splinter is a hypoechoic "halo" signifying adjacent edema, inflammation, and/or hemorrhage. Note that deep to the splinter, there is show shadowing artifact (yellow arrows). (b) **Artifacts associated with foreign bodies on ultrasound.** Ring down artifact is due to resonation of the original sound wave on the foreign body, thus leading to the repeated horizontal lines seen deep to the mass. Clean shadowing or attenuation artifact is the inability of the sound wave to penetrate through the dense mass, thus leading to an anechoic band deep to the mass. Dirty shadowing refers to scattering of sound waves off the mass, so that a mostly anechoic band is seen intermixed with transient hyperechoic textures.

Learning Point 7: Foreign bodies are typically denser than soft tissue and are therefore hyperechoic on ultrasound and may have hypoechoic surrounding rings or a halo sign.

8. EXPLANATION

B. Ultrasound. Ultrasound with a high-resolution linear probe showed a pooled sensitivity of 72% and specificity of 92% in a 2015 meta-analysis of 17 studies. Individual studies, however, report much higher test performances nearing 100% sensitivity and specificity and may reflect operator-dependent factors. X-ray, however, cannot show radiolucent materials, such as in this case, where we suspect wood. X-ray can be useful if there is concomitant concern for fracture. Ultrasound is a very useful first step in evaluating for suspected radiolucent foreign bodies, though it is not perfect for ruling out foreign material (Figure 11.24). Therefore, in the setting of a negative ultrasound but high clinical suspicion, advanced imaging such as a CT should be considered. CT scan, however, would not be the first-line imaging.

Figure 11.24 **Foreign body in hand.** A wooden splinter embedded in this patient's palm can easily be seen with a linear probe as a hyperechoic structure.

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Keywords/Tags: Clinical management, foreign body, sensitivity

Learning Point 8: Ultrasound can be helpful in identifying foreign bodies that are radiolucent (higher sensitivity and specificity than X-ray).

9. EXPLANATION

B. Use a low-frequency probe to best image superficial structures. Complete soft tissue imaging should include at least 2 orthogonal views (long and short axis of object/area in question). Comparison with adjacent normal tissue or the contralateral side can be especially helpful when findings are subtle. Dual mode can show both images on the screen at once. A high-frequency probe is usually the best choice for imaging superficial structures. A low-frequency probe generally is not the first choice for soft tissue imaging. However, it might be useful in patients with ample subcutaneous tissue if you suspect a deeper abscess.

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Keywords/Tags: Image acquisition, soft tissue

Learning Point 9: Complete soft tissue imaging should include at least 2 orthogonal views (long and short axis of object or area in question) and should often be compared with adjacent normal tissue or the contralateral side of the body.

10. EXPLANATION

D. This study is limited by air in the wound and cannot rule out retained foreign body. Air in a gaping wound or air under intact skin that was introduced from instrumentation can cast dirty shadowing, which can potentially hide foreign bodies. Certain body areas including finger web spaces and other concave areas are also challenging to assess for foreign body, but this can be somewhat mitigated by using an intracavitary probe or hockey-stick high-frequency probe and adjuncts like a water bath or by flooding a wound with saline. Scarred tissue also is challenging given its abnormal sonographic characteristics. Finally, very small foreign bodies (<2 mm) and those located adjacent to bone are also challenging to identify by ultrasound.

Both wood and gravel can be seen on ultrasound as hyperechoic structures with variable shadowing. The image in the question is most consistent with a collection of bubbles and resultant dirty shadowing, since it is in the setting of a gaping wound.

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Keywords/Tags: Air artifact, pitfalls, soft tissue

Learning Point 10: Understand pitfalls and limitations in ultrasound for foreign bodies.

11. EXPLANATION

D. Use ultrasound to evaluate for a fluid collection. If there is a collection, prepare for a drainage procedure and consider antibiotics as well; if no fluid or only a very small <0.5 mm collection is identified, treat empirically for cellulitis. The physical exam is suggestive of uncomplicated cellulitis so one might be tempted to treat clinically from exam alone (choice C). However, ultrasound findings can help make nuanced management decisions by identifying occult fluid collections especially when physical exam is not suggestive of abscess (Figure 11.25). In one study, ultrasound findings of an abscess changed management in approximately half of cases when this diagnosis was not highly suspected (Miss and Frazee 2014). This then avoids choice B, a painful blind drainage procedure that may be unsuccessful. It could be reasonable to trial diphenhydramine (choice A) especially if there is a significant pruritic component and minimal to no tenderness.

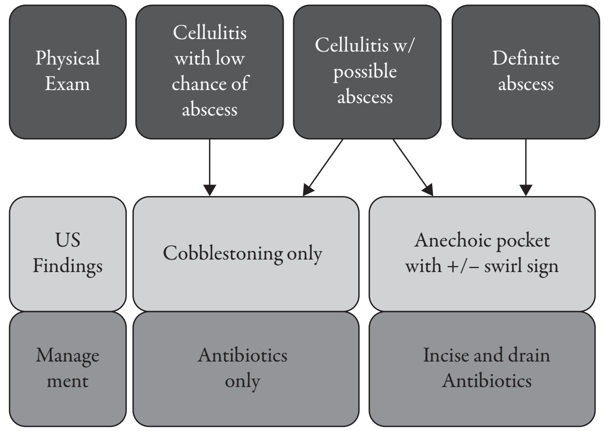

Figure 11.25 **Guide on the use of ultrasound in abscess evaluation.**

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Keywords/Tags: Clinical management

Learning Point 11: Soft tissue ultrasound can help guide clinical management of cellulitis and help determine if a drainable abscess is present.

12. EXPLANATION

B. Simple cyst. This image shows a smooth-walled, well-circumscribed, anechoic collection with posterior acoustic enhancement. This is most consistent with a simple cyst. Abscesses are variable in appearance but are often not completely anechoic; also, abscesses would be tender on exam. Complex cysts have internal echoes, septations, or irregular walls. Masses become more concerning for malignancy if they have irregular borders, are deeper rather than wide, or have posterior shadowing.

Radiologists use the Breast Imaging-Reporting and Data System (BI-RADS) to classify and risk stratify findings in breast imaging. Simple breast cysts are classified as BI-RADS

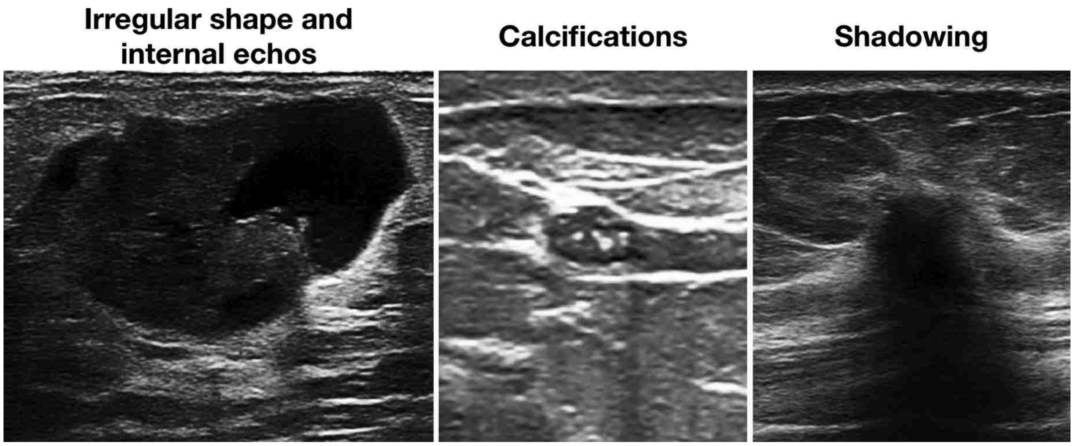

Figure 11.26 **Complex breast masses.** Features of complex breast masses include irregular shape, vascularity, and/or presence of internal echos, shadowing, or calcifications. These masses have a higher BI-RADS classification and warrant more urgent follow-up. From Figures 5.31, 5.33, and 5.34 of D'Orsi C. Breast Imaging Reporting and Data System. In: Lee CI, Lehman CD, Bassett LW, eds. *Breast Imaging.* Oxford, UK: Oxford University Press, 2018.

category 2, which deserves routine follow-up. Complex breast cysts correlate to BI-RADS 3–6 categories and warrant urgent follow-up for further imaging and/or tissue biopsy. While the classification of breast masses is not expected of the general clinician, it is important to recognize complex breast cysts from simple cysts, as recognition of complex cysts should prompt expedited follow-up (Figure 11.26).

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Keywords/Tags: Image interpretation, simple cyst

Learning Point 12: Simple breast cysts are round or oval; have smooth walls; do not have internal echoes, septations, or masses; and exhibit posterior acoustic enhancement. Clinicians should be able to recognize complex from simple cysts to counsel patients and to expedite management.

13. EXPLANATION

B. Hydrodissection. Once the foreign body is located, a needle can be used to inject local anesthetic in the same longitudinal plane as the foreign body (Figure 11.27, Video 11.9). This fluid can help dissect the foreign body away from the surrounding tissue, create a larger tract for the forceps and aid removal (French et al. 2014).

Hydrolocation can sometimes help sonographers identify needle location by injecting fluid, which creates anechoic contrast from the hyperechoic needle. Tip: Be careful not to inject air bubbles, which may obstruct view

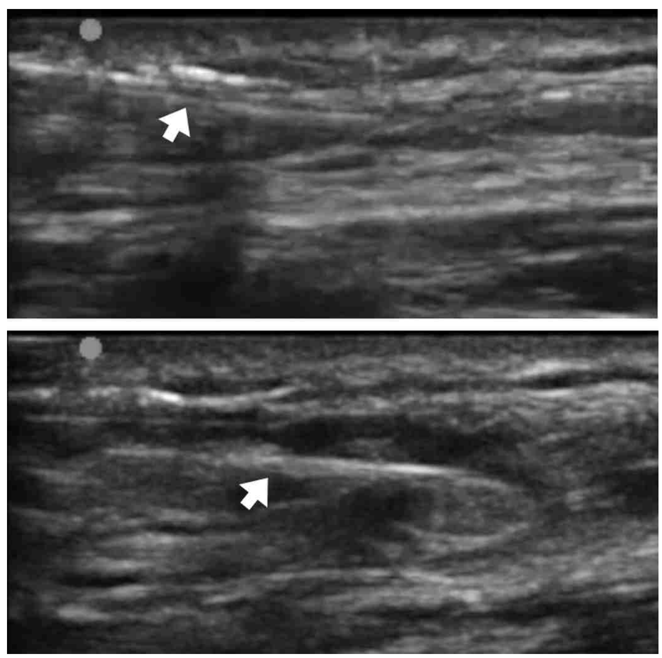

Figure 11.27 **Hydrodissection to evaluate foreign bodies.** The foreign body (arrow) is imaged in long axis in the top panel. A needle is then inserted via an in-plane approach from the left. Small aliquots of lidocaine or normal saline can be inserted to bathe the foreign body. The increased density contrast allows for better visualization of the foreign body as well as easier retrieval, as seen in the bottom panel.

due to artifact. Use of guide wire placement and graded dilation has been reported to remove foreign bodies. The wire and subsequent dilation can create a tract to allow for deeper advancement of forceps to remove deeper foreign bodies (French et al. 2014). Others advocate advancing a sterile needle until it touches the foreign body, then incising along that plane and, lastly, placing hemostat along the guide needle in the long axis to take hold of the object (Lulla et al. 2016).

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Keywords/Tags: Foreign body, foreign body removal, hydrodissection

Learning Point 13: Ultrasound can be used to help remove foreign bodies by identifying foreign body location, surrounding structures, use of hydrolocation, hydrodissection, and visualization of removal.

14. EXPLANATION

C. Normal lymph nodes have an echogenic center. Choice C is correct and is why lymph nodes are often described sonographically as appearing like "mini kidneys." Both kidneys and lymph nodes share structural similarities, with a central vascular hilum, echogenic sinus, and relatively more hypoechoic medulla and cortex. Normal and reactive lymph nodes tend to be elliptical with the short axis to long axis (S:L) ratio <0.5 (except submandibular nodes, which tend to be round). They also have an echogenic hilum as seen in Figure 11.28a.

Reactive lymph nodes tend to have more increased vascularity centrally due to inflammation. Normal lymph nodes may have some central vascularity or are avascular appearing, and often they are not seen on ultrasound. Malignant lymph nodes tend to have peripheral vascularity, be more round with S:L ratio >0.5 cm, and do not have an echogenic center (Figure 11.28b).

Malignant nodes may also have focal nodules, intranodal necrosis (anechoic areas), or calcifications (hyperechoic punctate densities).

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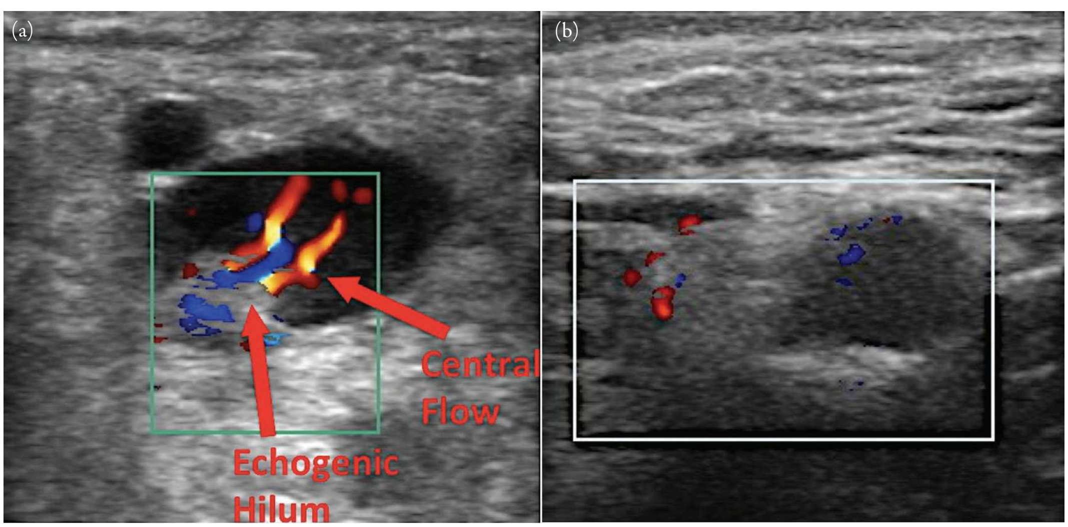

Figure 11.28 (a) **Reactive lymph node.** Long axis view of a reactive lymph node with echogenic center and evidence of central flow on color Doppler. (b) **Malignant lymph node.** Long axis view of a malignant lymph node. This can be distinguished as a malignant lymph node because it is more round with S:L ratio >0.5cm and does not have an echogenic center. Also, it has a small amount of peripheral blood flow unlike normal and reactive lymph nodes, which tend to have more central blood flow.

Bialek EJ, Jakubowski W. Mistakes in ultrasound diagnosis of superficial lymph nodes. *J Ultrason*. 2017;17(68):59–65. doi:10.15557/JoU.2017.0008.
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Keywords/Tags: Lymph node, benign, malignant, soft tissue, lymphoma

Learning Point 14: Benign and reactive lymph nodes can be distinguished from malignant lymph nodes by looking at size and echogenicity and using power color Doppler.

15. EXPLANATION

B. Malignant tumor. Superficial masses are usually located in the skin and subcutaneous tissue above the fascia, which separates the subcutaneous layer from deeper muscular layer. A malignant mass usually has a size >5 cm, is deep in location, is heterogeneous, has increased vascularity, and may have areas of necrosis. When the size of the mass is small and the location is superficial, the relationship to fascia can help to differentiate whether it is a malignant or benign mass. Obtuse angles between the superficial fascia and the subcutaneous mass also strongly suggest malignancy.

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Keywords/Tags: Soft tissue neoplasms, ultrasonography, benign vs. malignant mass

Learning Point 15: Malignant masses can invade the deeper layers of soft tissue.

16. EXPLANATION

A. Solid mass with a heterogeneous echo pattern and blood flow. Dupuytren's disease is a thickening of the palmar aponeurosis due to disordered fibroblast growth. It is the most common fibromatosis, which can be characterized as superficial (e.g., palmar, plantar) or deep (e.g., intra-abdominal). About 2% of the general population are affected either by palmar or plantar fibromatosis. Diabetes, alcoholism, hypothyroidism, and age >65 are risk factors. Local injection with steroids and/or anesthetic can help to alleviate symptoms, and surgery can restore function. However, there is about a 20% to 40% recurrence rate.

Sonographically, fibromas appear as well-defined hypoechoic solid masses with internal heterogeneous echo patterns. They are usually superficial to either the flexor tendon in palmar fibromas or the plantar fascia in plantar fibromas. Internal blood flow can be visualized with color Doppler. Patients should be referred for additional imaging if there is uncertainty or concern for malignancy. Choice B is suggestive of hematoma, choice C is suggestive of ruptured epidermal inclusion cyst, and choice D is concerning for malignant mass.

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Keywords/Tags: Soft tissue lesions, fibromatosis, imaging, ultrasound

Learning Point 16: Palmar and plantar fibromas are common, superficial soft-tissue masses. On ultrasound they appear as well-defined and solid masses superficial to fascia or tendons and often with some vascularity.

17. EXPLANATION

D. Suture granuloma. This is the classic appearance of a suture granuloma, which forms as a result of the body's inflammatory response to retained suture material. There is a hypoechoic collection (straight arrows) with "rail-like" double linear bands that correspond to retained suture material. Suture granulomas may display some central flow on color Doppler if inflammation is present. Abscesses and hematomas are variable in appearance in terms of echogenicity (usually hypo or isoechoic), as well as compressibility. They do not tend to have central vascularity. In the example of a hematoma, they are associated with recent trauma. Given that tumor recurrence is among the differentials for new neck mass in a patient with recent history of a thyroid tumor, this is a scenario where additional imaging should be pursued for confirmation of the diagnosis. In

situations where there is no concern for malignancy, suture granulomas can be explored and excised.

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Keywords/Tags: Suture granuloma, ultrasound, soft tissue

Learning Point 17: Suture granulomas are a common source of postsurgical pain that is due to the inflammatory response to small, retained fragments of sutures.

18. EXPLANATION

C. This is most likely a hematoma because he has no infectious symptoms, and he is on anticoagulation and status post trauma. In the setting of acute trauma in a patient on anticoagulation who lacks infectious symptoms, this finding on ultrasound is most likely a hematoma. Hematomas are often anechoic and have irregular borders as seen in this shoulder hematoma in Figure 11.29a.

However, it can be difficult to differentiate hematomas from mimics without clinical information to correlate with sonographic findings. Choice A and B are incorrect because hematomas can be homogenous, often immediately after injury, but as they coagulate may have internal echoes that make them appear more heterogenous as seen in Figure 11.29b.

Because hematomas can mimic many pathologies, clinical correlation is very important for diagnosis. If there was no trauma present, a broader differential should include aneurysm, pseudoaneurysm, coagulopathy, cyst, soft tissue sarcoma, or other soft tissue tumor and infection. Given this man's history, hematoma is most likely, although there have been many case reports in the literature of sarcomas in children being misdiagnosed as hematomas.

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Keywords/Tags: Soft tissue, hematoma, abscess, sarcoma, tumor

Learning Point 18: Clinical correlation is important for the sonographic diagnosis of hematoma. Hematomas can be heterogenous due to thrombus formation.

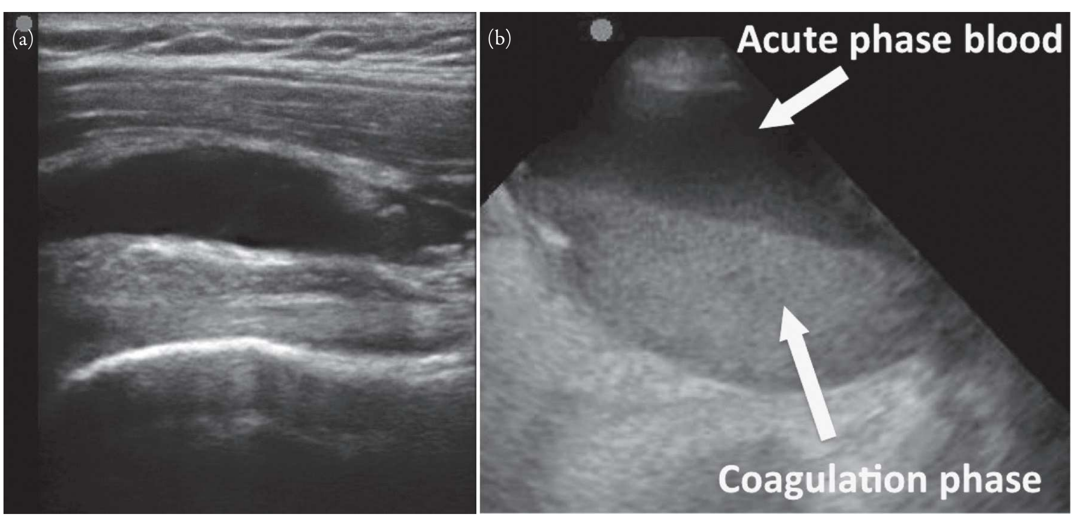

Figure 11.29 (a) **Hematoma over the humeral head on ultrasound.** (b) **Both acute and coagulated blood seen within hematoma.**

19. EXPLANATION

C. An ovoid, heterogeneous, hypoechoic mass with hyperechoic swirls and posterior acoustic enhancement in the dermal layer with a tract leading to the skin surface. This is consistent with an epidermoid cyst (also called sebaceous cysts). These small, keratin-filled cysts arise from the epidermal layer most commonly on the scalp, face, and extremities, though they can be anywhere. On ultrasound, they appear as small, well-circumscribed, predominantly hypoechoic ovoid or spherical masses, though some may be lobular. The mass arises from the skin layer. The echotexture is often heterogeneous due to the keratin filling. They tend to have posterior acoustic enhancement and edge artifact. Sometimes, a tract to the skin surface can be seen (Figure 11.30). Choice A describes the findings of a simple cyst. The mass described in choice B is concerning for malignancy given ill-defined borders, heterogeneous echotexture, increased Doppler flow, and, most importantly, invasion of multiple tissue layers. Choice D describes findings consistent with a lipoma.

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Lee HS, Joo KB, Song HT, et al. Relationship between sonographic and pathologic findings in epidermal inclusion cysts. *J Clin Ultrasound*. 2001;29 (7):374–383.

Keywords/Tags: Mass, benign mass, diagnosis

Learning Point 19: Epidermoid cysts are ovoid, heterogeneous, hypoechoic masses with hyperechoic swirls and posterior acoustic enhancement in the dermal layer, often with a visualized tract leading to the skin surface.

20. EXPLANATION

A. Use alcohol wipes to clean the probe. Alcohol wipes can be damaging to many ultrasound probes and machines so they are not recommended for disinfection purposes. The largest concerns for infection control with use of

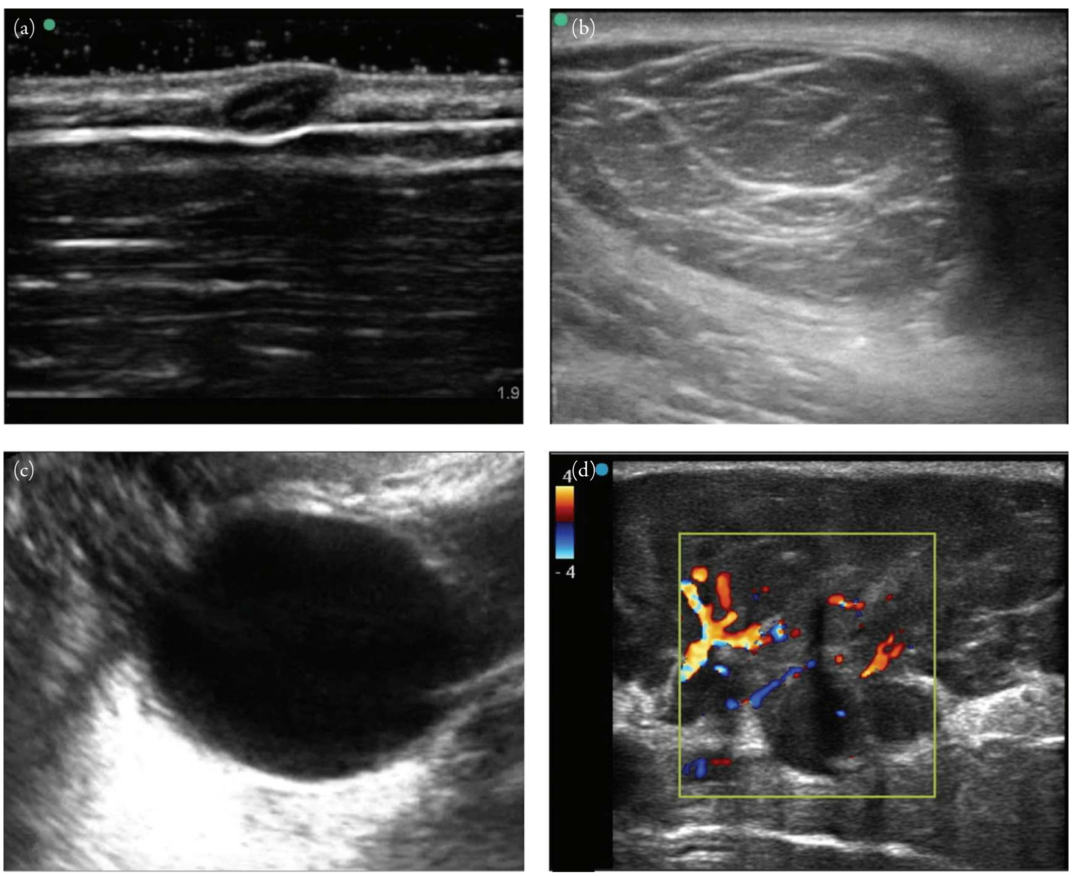

Figure 11.30 **Variable appearance of cysts on ultrasound.** Panel (a) shows an epidermoid cyst, which is typically small (<1cm), well-circumscribed, with a heterogeneous echotexture, and located in the skin layer. Panel (b) shows a lipoma, which is typically larger, isoechoic, and has internal hyperechoic swirls. Panel (c) shows a simple cyst, which is also round and well-circumscribed, with no internal echoes, and demonstrating posterior acoustic enhancement. Panel (d) shows a concerning complex cyst that is heterogeneous, vascular, and involves multiple soft-tissue layers.

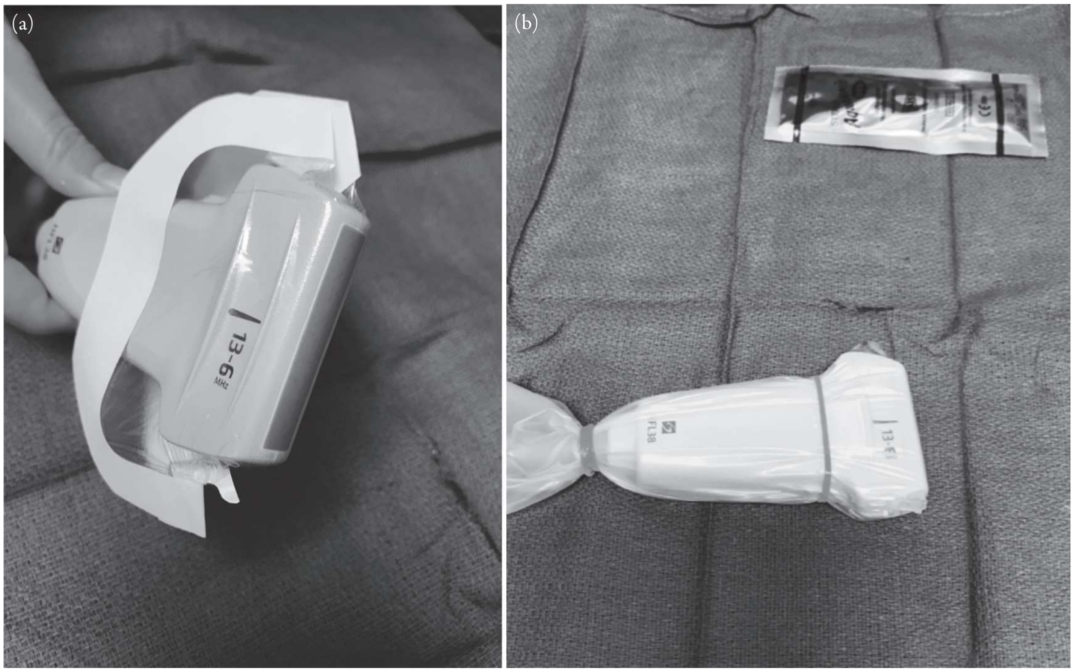

Figure 11.31 (a) **Tegaderm barrier method.** A clear, adhesive-backed film like Tegaderm can be placed on the transducer to act as a barrier method. The wax paper border can be left intact to facilitate removal, or discarded. (b) **Sterile gel and cover.** Under sterile precautions, a portion of the sterile gel is placed in the probe cover, followed by the actual transducer. The gel minimizes air artifact. Rubber bands secure the cover near the transducer head as well as at the cable-transducer interface.

ultrasound is when the probe contacts nonintact skin or fluids or with use of the endocavitary probe. Using a Tegaderm© or probe cover and sheath (either a product specifically made for this or a makeshift substitution such as a sterile glove) are helpful infection control methods, though the efficacy of the Tegaderm© method has not been extensively studied (Figure 11.31a and Figure 11.31b). More recent recommendations are straying away from Tegaderm© and recommend a probe cover. Sterile ultrasound gel or lubricant should be used as the coupling agent in these cases. Between scans, probes should be cleaned of residual gel, and chemical cleaners such as those containing a quaternary ammonium compounds (like in Sani-Cloth©) are helpful in eliminating bacteria as well as viruses and fungal pathogens. Clinicians should note the effective contact time, or the time disinfection agents should be allowed to work, prior to reusing the transducer. Typically, contact times are 2 to 10 minutes. When barrier methods are used, a chemical disinfectant should be used as well. It is important that hospitals develop clear plans for maintaining and disinfecting ultrasound machines. A machine's manufacturer can be helpful in guiding an appropriate infection control regimen.

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Shokoohi H, Armstrong P, Tansek R. Emergency department ultrasound probe infection control: challenges and solutions. *Open Access Emerg Med*. 2015;7:1–9. doi:10.2147/OAEM.S50360.

Keywords/Tags: Infection control

Learning Point 20: Various barrier as well as chemical cleaning methods can help with infection control for ED ultrasound machines.

21. EXPLANATION

D. 1: Gel pad; 2: Epidermis; 3: Dermis; Blue Circle: Tendon; Red Circle: Vascular Structure; Yellow Circle: Median Nerve; 4: Bone; 5: Muscle. The epidermis is a thin, linear hyperechoic structure. The dermis has variable thickness and is also hyperechoic, while subcutaneous tissue is hypoechoic due to fat lobules with fibrous surroundings (Gaitini 2013). The median nerve like all nerves has a "honeycomb" appearance in an axial view or appears as a bundle of hypoechoic dots or nerve bundles surrounded by a hyperechogenic rim (epineurium). In the longitudinal view, tendons are a well-formed mix of parallel hyperechogenic and hypoechogenic lines (Kowalska and Sudoł-Szopińska 2012) . In the axial view seen above, the tendon is a well-defined bundle with

punctate echogenicity. Vascular structures are generally round, well-circumscribed anechoic structures. Muscle is hypoechoic with internal hyperechogenic striations. The bone margin appears as a discrete hyperechoic line with acoustic shadowing.

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Kowalska B, Sudoł-Szopińska I. Normal and sonographic anatomy of selected peripheral nerves. Part I: sonohistology and general principles of examination, following the example of the median nerve. *J Ultrason*. 2012;12(49):120–130. doi:10.15557/JoU.2012.0001.

Keywords/Tags: Soft tissue, anatomy, normal, nerve, muscle, tendon, bone

Learning Point 21: Identification of various layers seen in soft tissue ultrasound.

22. EXPLANATION

A. Lipoma. These often are elongated or ovoid masses of variable echogenicity (though most commonly isoechoic) that may have more curved echoic lines within. They do not tend to have posterior acoustic enhancement and have no to minimal doppler flow. Reactive lymph nodes (choice B) have characteristic "kidney" appearance with hyperechoic hilum as well as characteristic vascular pattern (see Figures 11.10 and 11.29). Epidermoid cysts (choice C) appear as small, well-circumscribed predominantly hypoechoic ovoid or spherical masses, with posterior acoustic enhancement and edge artifact. Abscesses (choice D) can be variably echogenic and can be well or ill circumscribed; there may also be visible movement of internal echogenic material know of fluid contents "squish" or "swirl sign" when pressure is applied (Figure 11.19b, Video 11.6).

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Keywords/Tags: Image interpretation

Learning Point 22: Identify usual sonographic findings of lipomas.

23. EXPLANATION

B. The patient should Valsalva while the probe is placed over the lower abdomen parallel to the inguinal canal with inferior epigastric vessels located laterally. Ultrasonography has been shown to be accurate in identifying groin hernias and differentiating between direct and indirect inguinal hernias, as well as the more rare femoral hernias (Figure 11.32). Direct inguinal hernias will be seen in the superficial inguinal triangle (1, Hesselbach's triangle) bordered by the rectus muscle (R) medially, the epigastric vessels superiorly, and the inguinal ligament (L) inferior-laterally. Indirect inguinal hernias (2) will travel in the inguinal canal (C) and be visualized in the scrotum. Femoral hernias (3) will be visualized just lateral to the inguinal ligament and close to the femoral vessels.

When evaluating for a groin hernia, the probe should be positioned over the inguinal triangle in both long and short axis. Asking the patient to Valsalva will increase intrabdominal pressure and therefore increase visibility of hernias (Figure 11.33a, Video 11.11).

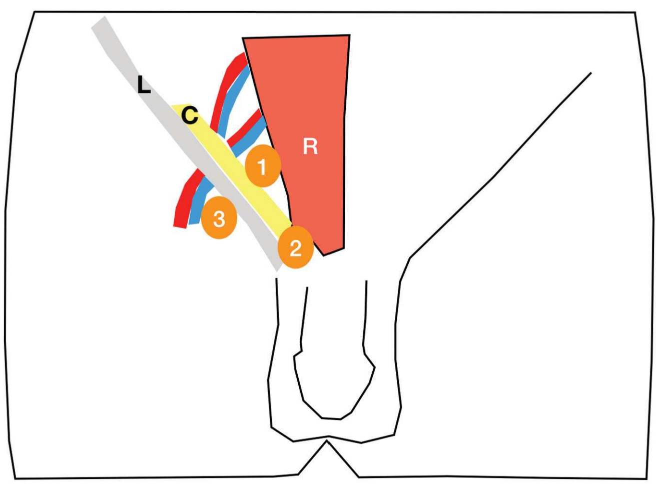

Figure 11.32 **Location of groin hernias.**

If unable to visualize a hernia in a supine patient, it may become apparent after asking the patient to stand (Jaconbsen et al. 2015). Fat in a hernia appears hyperechoic. A defect in the fascia can be identified as two hyperechoic linear densities deep to the herniated contents as seen in the image of a ventral hernia in Figure 11.33b.

Bowel loops within the hernia may show peristalsis (Jamadar et al. 2006) but may not if bowel is incarcerated or strangulated. Sonographic signs of bowel strangulation such as lack of peristalsis, lack of blood flow visualized on Doppler ultrasound, and bowel edema have been described; however, these findings have not been confirmed by surgical pathology (Siadecki et al. 2014).

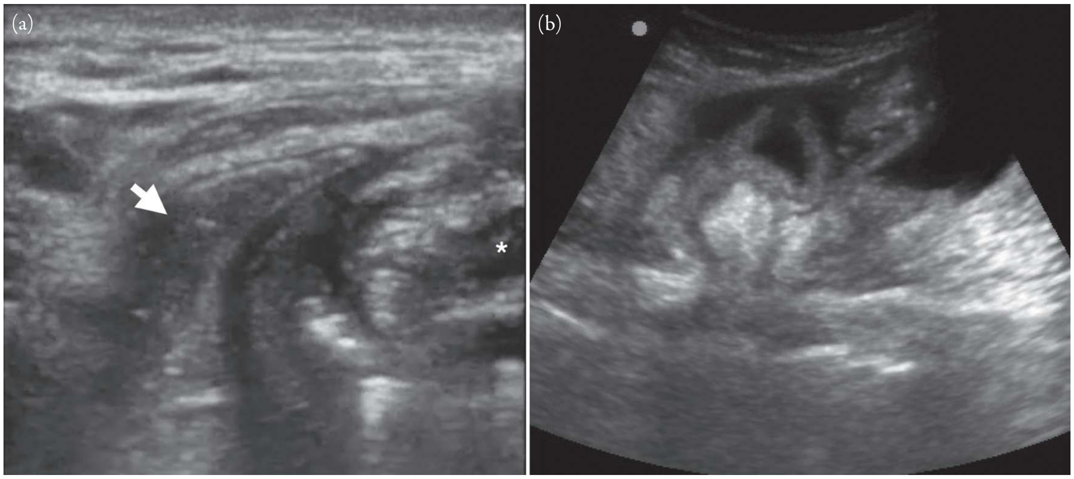

Figure 11.33 (a) **Direct inguinal hernia.** This image shows this left direct inguinal hernia (arrow) originating from the inguinal canal. The femoral vessels (*) are just lateral to it. (b) **Ventral hernia.**

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Keywords/Tags: Inguinal hernia, hernia

Learning Point 23: Inguinal hernias are best visualized during Valsalva or when the patient is standing. Herniated bowel can sometimes be identified by peristalsis.

24. EXPLANATION

C. There is subcutaneous air, which obscures evaluation of pneumothorax. This image shows subcutaneous emphysema which obscures visualization of deeper structures including the pleura. Therefore, absence of pleura sliding cannot be assessed. Subcutaneous emphysema is hyperechoic and often has vertical artifacts that continue to the bottom of the screen similar to B-lines in appearance. Air can easily be misinterpreted as the pleural line because both appear as linear hyperechoic densities. However, E-lines (arrow) do not arise from the pleura and are not synchronous with respiratory movements (José et al. 2016). When evaluating for a pneumothorax, the sonographer should identify 2 ribs and visualize the pleural line deep to these structures. The pleural line should also be at the same depth on both sides of the chest. If ribs cannot be identified, it is likely due to artifact arising from the air within the tissue superficial to the lung. While subcutaneous emphysema is often associated with a pneumothorax, a pneumothorax cannot be diagnosed sonographically without visualizing the pleural line (Volpicelli 2011).

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Volpicelli G. Sonographic diagnosis of pneumothorax. *Intensive Care Med*. 2011;37(2):224–232. doi:10.1007/s00134-010-2079-y.

Keywords/Tags: Subcutaneous emphysema, pneumothorax, lung ultrasound, soft tissue

Learning Point 24: Subcutaneous air is hyperechoic and has associated E-lines, which can be mistaken for normal pleura and may obscure visualization of pleura and a pneumothorax.

12.

OCULAR ULTRASOUND

Stephanie Tseeng, Sharmin Kalam, and S. Zan Mehtab Jafry

QUESTIONS

1. A 58-year-old obese male with diabetes mellitus presents with sudden painless vision loss of his left eye. Visual acuity in affected eye is to hand motion only. You attempt a fundoscopic exam but only note an absence of red reflex with a grey appearance instead. Visual field testing reveals a superior altitudinal field defect in the left eye only. You wish to assess for retinal versus vitreous detachment. Which of the following combination of probe, exam preset, and scan mode best optimize the ocular point-of-care ultrasound (POCUS) examination?

A. Linear 3–5 MHz, vascular, Doppler
B. Curvilinear 3–5 MHz, small parts, M-mode
C. Linear 7.5–10 MHz, small parts, B-mode
D. Endocavitary 5–7.5 MHz, vascular, Doppler

2. A 10-year-old boy presents with right eye pain and redness after watching his father perform a welding project in the garage without goggles. Though no obvious deformity exists, you suspect ocular foreign body and perform ocular ultrasound. Upon closing his eyes, the patient reports no discomfort and the exam is initiated as shown in Figure 12.1. Seconds later the patient becomes lightheaded, nauseous, and passes out. Which of the following most likely could have prevented this patient's reaction?

A. Placing less gel on patient's eye
B. Anchoring fingers on patient's temporal or brow bone
C. Pretreatment with an ocular anesthetic
D. Pretreatment with a mydriatic

Figure 12.1

3. A 37-year-old male complains of vision loss of his right eye. On exam, his visual acuity is 20/200 in the right eye and 20/40 in left eye with a normal fluorescein exam. You wish to assess for intraocular pathology. What steps would you take for proper image acquisition technique in junction with patient comfort?

1. Choose linear transducer and apply a small sterile cover (i.e., Tegaderm) over closed eyelid.

2. Place the patient in supine or semi-recumbent position and with eyes looking in forward direction.
3. Apply gentle light pressure while scanning in transverse and sagittal plane and adjust focus and gain during the exam.
4. Place copious amount of gel to closed eyelid for better contact.

A. 2, 4, 1, 3
B. 2, 1, 4, 3
C. 2, 4, 3, 1
D. 4, 2, 3, 1

4. A 65-year-old female presents with progressive painless vision loss over several years, now with significant impairment. Her visual acuity is 20/100 in the left eye and 20/200 in the right eye. You obtain the ocular ultrasound (see Figure 12.2, Video 12.1), which shows what disease process?

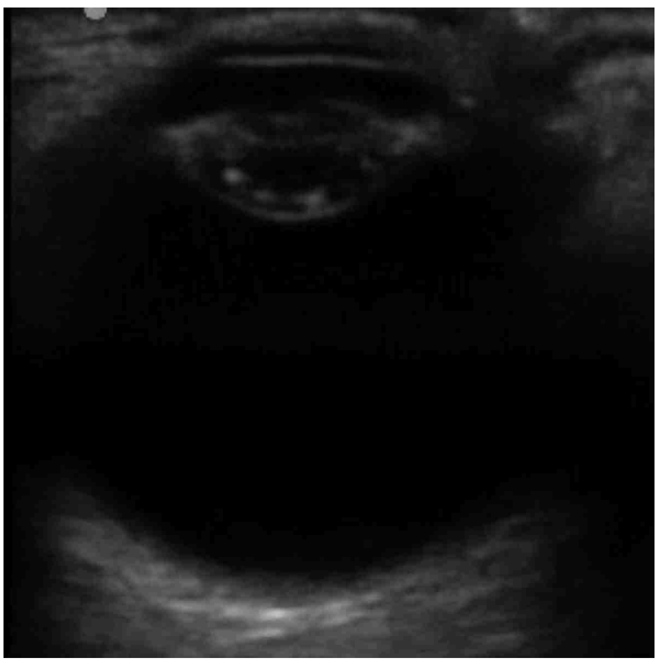

Figure 12.2

A. Lens dislocation
B. Cataract
C. Vitreous hemorrhage
D. Retinal detachment

5. Which of the following is *not* an indication for noninvasive bedside ocular ultrasound exam?

A. Acute vision loss or unexplained ocular pain
B. Eye trauma
C. Assess for acute glaucoma
D. Evaluation of elevated ICP

6. A 29-year-old female with a history of Marfan syndrome presents with progressive decrease in vision and worsening glare in both eyes. On physical exam, her pupils are equal and reactive to light with extraocular movement in intact. Acuity of both eyes are 20/40 and 20/50 with no evidence of afferent pupillary defect. You suspect lens subluxation. Which structure is likely involved in Figure 12.3?

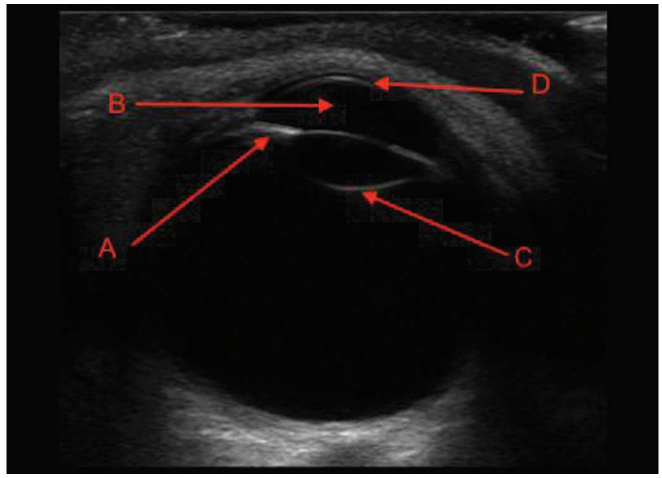

Figure 12.3

A. See Figure 12.3
B. See Figure 12.3
C. See Figure 12.3
D. See Figure 12.3

7. A 75-year-old male presents with blurred vision for 5 days. The patient notes he woke up with mild blurred vision, which improved with eye rubbing but he developed significant redness and edema of the eyelid and periorbital region. Your clinical diagnosis is periorbital cellulitis, but you wish to evaluate underlying ocular structures to ensure there are no abnormalities to underlying structures. The ocular ultrasound is shown in Figure 12.4. Which of the following corresponds to the labeled structures from anterior to posterior?

A. Pupil, lens, vitreous, optic nerve
B. Cornea, iris, vitreous, retinal artery
C. Cornea, pupil, vitreous, optic nerve
D. Pupil, cornea, vitreous, retinal artery

8. A 47-year-old male was physically assaulted with a bat in an alley and sustained head and facial trauma. He presents with left eye pain and blurry vision. On exam, you see left eyelid swelling and ecchymosis with a teardrop pupil. You perform a slit lamp exam and see a positive Seidel

Figure 12.4

sign and therefore suspect a globe rupture. Which of the following is a sonographic finding of a globe rupture?

A. "Washing machine" sign
B. Anterior chamber collapse
C. "Guitar pick" sign
D. Anterior chamber expansion

9. A 32-year old male is brought in by emergency medical services after being assaulted. He has significant facial trauma and complains of eye pain and vision loss of this left eye. You try to examine his eye but there is significant orbital swelling and the patient is unable to open his eyes. You perform a bedside ocular ultrasound (Figure 12.5, Video 12.2). What is the next best step in management?

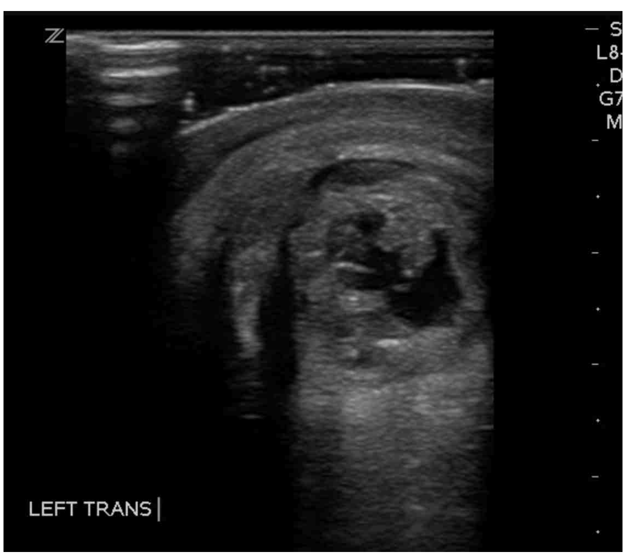

Figure 12.5

A. Perform emergent lateral canthotomy to relieve intraocular pressure.
B. Consult ophthalmology for laser photocoagulation.
C. Start antibiotics and topical cycloplegics.
D. Place eye shield, update tetanus, and emergent ophthalmology consult.

10. A 68-year-old male presents with blurred vision after a mechanical fall in which he tripped on a curb and stumbled forward with his face hitting a metal pole. Along with blurred vision and perception of floaters, the patient reports pain only of the eye and face at the site of contact. The patient is noted grossly to have right eyelid edema and periorbital ecchymosis with intact extraocular movements and pupil reactivity. On slit lamp exam, the patient is noted to have subconjunctival hemorrhage and moderate hyphema. Visual acuity reveals only light perception in the right eye and 20/20 in the left eye. You perform an ocular ultrasound (see Figure 12.6). What is this patient's diagnosis?

Figure 12.6

A. Retinal detachment
B. Papilledema
C. Lens dislocation
D. Retrobulbar hematoma

11. A 34-year-old diabetic male presents with atraumatic acute visual changes for 3 days in the left eye. He had noticed intermittent floaters, which progressed to what he describes now as "looking out of a rainy window." Gross and slit lamp exam are normal. Visual acuities are left eye (OS) 20/200 and right eye (OD)

20/20. Visual field testing reveals a deficit in the superior field. You perform an ocular ultrasound which shows the images in Figure 12.7 and Video 12.3. What is the diagnosis?**

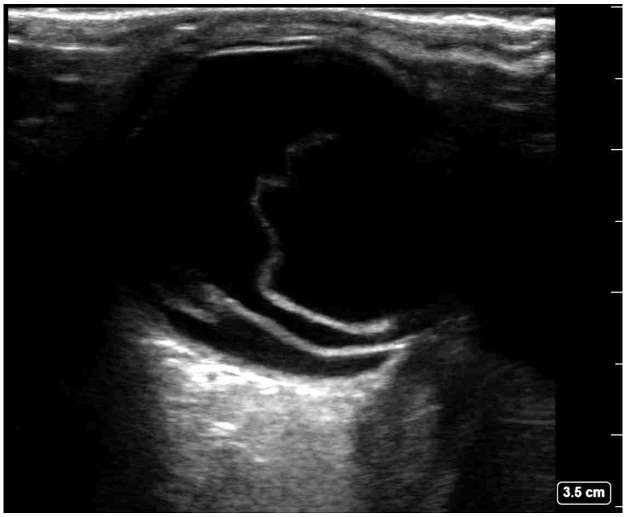

Figure 12.7

A. Retinal detachment
B. Posterior vitreous detachment
C. Vitreous hemorrhage
D. Central retinal vein occlusion

12. A 45-year-old male presents with blurred vision in the right eye after being hit with a volleyball to the face. The patient has small periorbital ecchymosis and visual acuity is 20/70 in the right eye and 20/15 in the left eye. You perform a fundoscopic exam showing a large red opacity lateral to the macula. You then perform the ocular ultrasound shown in Figure 12.8 and Video 12.4. Which next step would help identify the pathology?

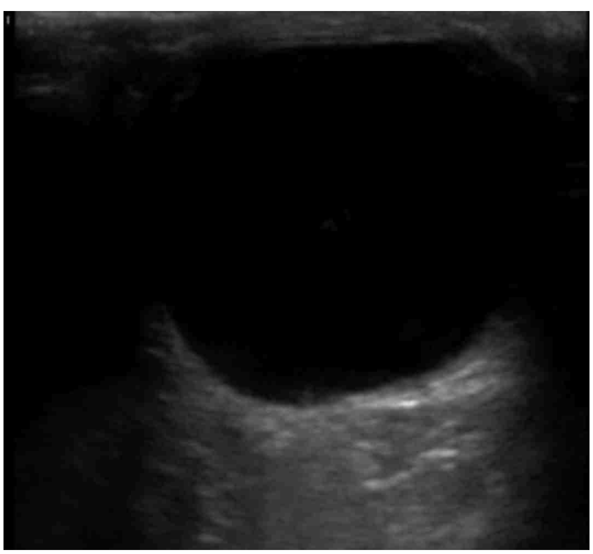

Figure 12.8

A. Color Doppler
B. Increase depth
C. Decrease depth
D. Increase gain

13. A 65-year-old female with history of diabetes presents with 3 weeks of progressive painless vision loss. She reports the symptoms initially began in the left eye, then progressed to the right with significant photopsia. You perform an ocular ultrasound shown in Figure 12.9 and Video 12.5. What is the diagnosis?

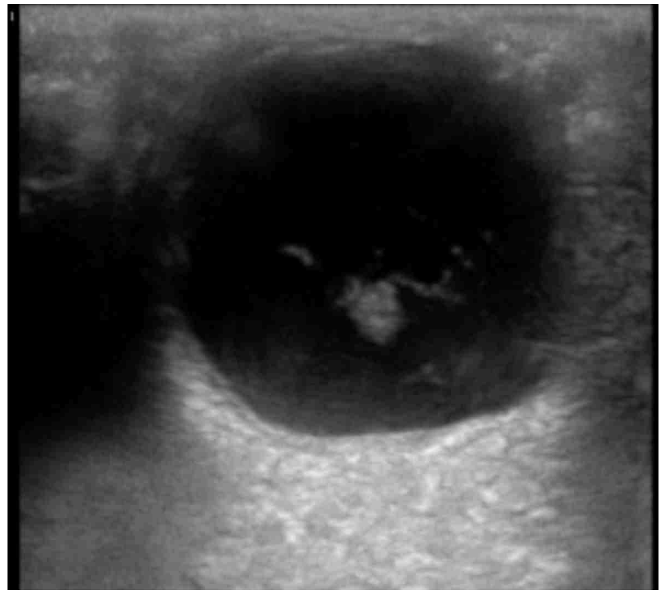

Figure 12.9

A. Lens dislocation
B. Papilledema
C. Vitreous detachment
D. Retinal detachment

14. A 26-year-old obese female presents with diffuse intermittent headache frequently that is worse upon awakening for the past week. She noted mild diplopia but denies other neurological complaints, nausea, or vomiting. She has no prior history of migraine headaches or head trauma. You are concerned for idiopathic intracranial hypertension (IIH) and want to assess for papilledema. What is considered an abnormal optic nerve sheath diameter (ONSD)?

A. Greater than 3 mm measured at 2 mm posterior to globe
B. Greater than 4 mm measured at 3 mm posterior to globe
C. Greater than 5 mm measured at 4 mm posterior to globe
D. Greater than 5 mm measured at 3 mm posterior to globe

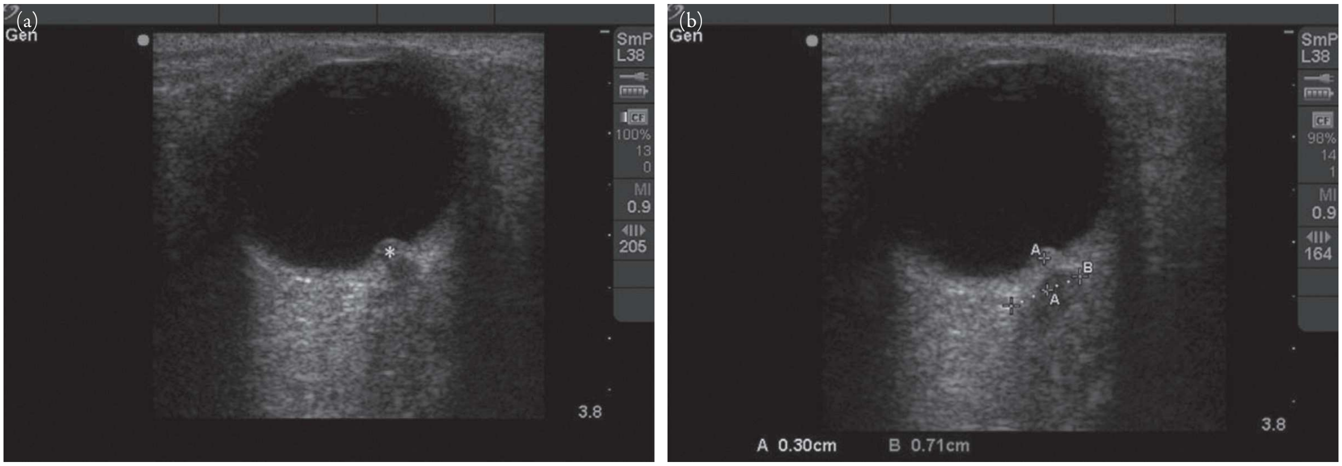

Figure 12.10

15. A 32-year-old female with past medical history of obesity reports a new severe headache and blurred vision for 5 days. She reports the onset was gradual but rapidly progressive and unresponsive to pain medication. The patient is found to have a negative head computed tomography (CT). A bedside ultrasound is performed (Figure 12.10). What is the next best step in management?

A. Neurosurgery consult for decompression
B. Outpatient neurology consult
C. Lumbar puncture with CSF drainage
D. Emergent lateral canthotomy

16. A 47-year-old female with a history of multiple sclerosis (MS) arrives to your emergency department with a 3-day history of right-sided progressive ocular pain at rest with ocular movement and intermittent visual "fogginess" in that same eye. She states the pain is associated with dull retroorbital headache 6/10, constant. Visual acuity is OD 20/60 and OS 20/25. On fundoscopic exam you note blurred optic disc margins and an afferent pupillary defect on the right eye. The left eye is normal. Which of the following pairs both the appropriate technique to evaluate optic neuritis and the finding that supports diagnosis of optic neuritis?

A. M-mode for rapid eye movement with amplitude testing; bilaterally increased ONSD
B. Color Doppler flow to measure changes in retrobulbar vascular dynamics and optic nerve diameter; unilaterally increased ONSD
C. 2D fractional shortening; unilaterally decreased ONSD
D. Optic nerve length, bilaterally increased ONSD

17. A 57-year-old male presents with sudden -onset severe headache during sexual intercourse with his wife. He has associated nausea, vomiting, and a near-syncopal episode. He denies a history of migraine headaches. Which of the following image is *most* specific for diagnosis of papilledema?

A. Figure 12.11a see figure on next page
B. Figure 12.11b see figure on next page
C. Figure 12.11c see figure on next page
D. Figure 12.11d see figure on next page

18. A 35-year-old female with a history of obesity presents with severe headache, diplopia, and nausea with vomiting. Physical exam reveals a left sixth cranial nerve palsy but otherwise normal neurologic exam. Visual acuity is 20/50 bilaterally. While awaiting the CT scan of the head, you perform an ultrasound to evaluate ONSD. Which of the following is the best initial technique?

A. Figure 12.12a see figure on next page
B. Figure 12.12b see figure on next page
C. Figure 12.12c see figure on next page
D. Figure 12.12d see figure on next page

19. An 84-year-old female with a history of diabetes, hypertension, and stroke presents with right eye pain

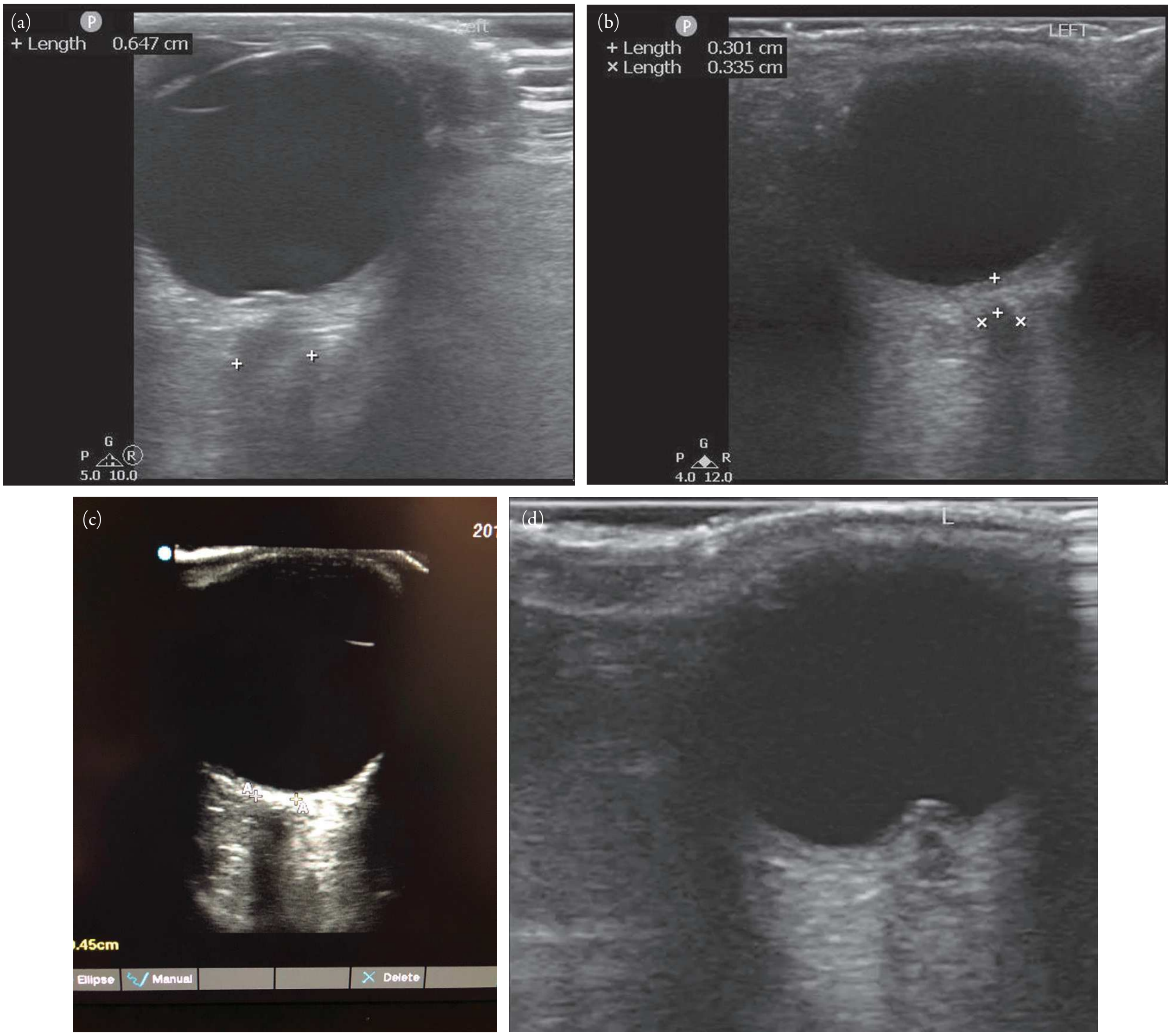

Figure 12.11

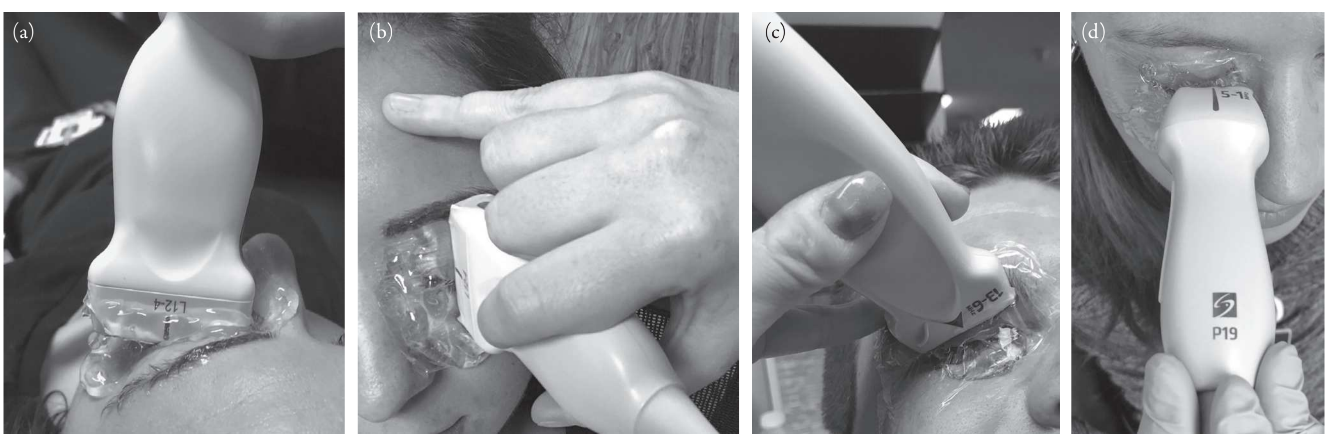

Figure 12.12

and vision loss. Fundoscopic exam reveals a pale retina with cherry red spot. You suspect CRAO, so you consult ophthalmology emergently and start acetazolamide and sublingual isosorbide dinitrate. While awaiting further recommendations, you perform bedside ultrasound to assess ocular blood flow (see Figure 12.13). Figure 12.13 with associated labels corresponds to which vessels?

A. I. Central retinal artery, II. ophthalmic artery, III. ciliary arteries
B. I. Ciliary arteries, II. central retinal artery, III. ophthalmic artery
C. I. Central retinal arteries, II. Ciliary arteries, III. Ophthalmic artery
D. I. Ophthalmic artery, II. ciliary arteries, III. central retinal artery

20. A 26-year-old male presents with left eye irritation, watery discharge, and blurry vision. His symptoms started while he was grinding metal without eye protection and felt some debris get in his eyes. He reports a gritty sensation in that same eye. On exam you note an injected, watery left eye. Visual acuity is 20/20 bilaterally. Slit lamp exam reveals conjunctival injection with a positive Seidel's sign. You obtain the ultrasound of the eye shown in Figure 12.14. What is the diagnosis?

A. Retrobulbar hematoma
B. Ruptured globe
C. Corneal abrasion
D. Ocular foreign body

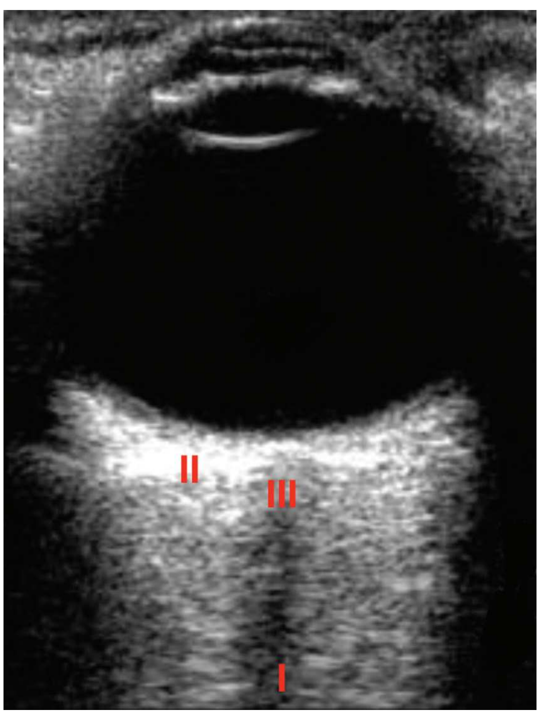

Figure 12.13

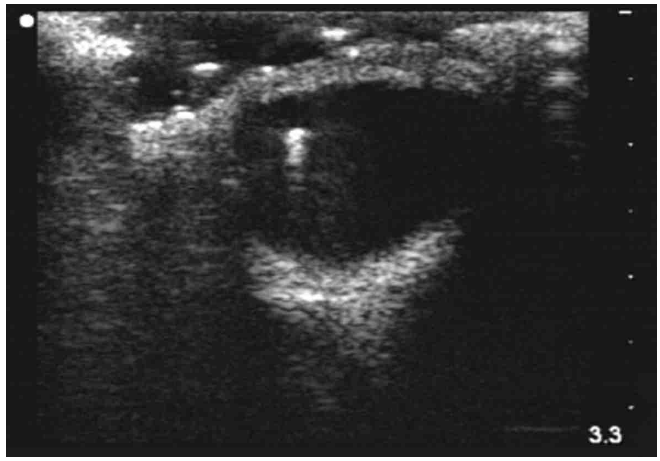

Figure 12.14

21. A 19-year-old male was assisting his dad with woodcutting in their garage without eye protection when he felt debris go into his eye. The patient has had ongoing foreign body sensation since then. You note conjunctival injection with a corneal abrasion and a positive Seidel's sign. You also find a loose small wooden splinter under the eyelid, which is removed. Visual acuity is normal. Your bedside ultrasound shows no abnormalities. Of the following, what is the next best step in the patient's management?

A. CT
B. Magnetic resonance imaging (MRI)
C. Discharge home with erythromycin
D. X-ray

22. On shift sign-out, your colleague tells you about a 32-year-old male complaining of acute right-sided vision loss after a high-speed motor vehicle accident. He reports that on bedside ultrasound he sees no RD and shows you the ultrasound in Figure 12.15. What changes could be made to improve the study?

Figure 12.15

A. Probe type
B. Depth
C. Preset
D. All of the above

23. A 23-year-old female with a history of von Willebrand's disease, polysubstance abuse, and depression presents with new right eye pain and decreased visual acuity after an altercation at the bar during which the patient was punched in the right eye. Grossly there is significant ecchymosis of the right periorbital region, with EOMI and mild exophthalmos. Visual acuity is OD 20/100 and OS 20/25. Slit lamp exam of the right eye shows a sluggish right pupil but otherwise no obvious abnormalities. You obtain the ultrasound shown in Figure 12.16. What is the most likely diagnosis?

A. Globe rupture
B. Posteriorly placed foreign body
C. Retrobulbar hematoma
D. Increased ICP

24. A 38-year-old male presents with a 5-day history of floaters and decreased visual acuity of the right eye. He denies any trauma, injury, or new medication. You discuss your recommendation to perform an ocular ultrasound exam. Prior to beginning your ultrasound exam of his right eye, your patient asks you "Is there any risk of damage to my eye from ultrasound?" What is the most appropriate response?

A. "The eye shield placed over the eye during the exam will act to counteract any of the deleterious effects of the ultrasound exam."
B. "None, even with suspected globe rupture."

Figure 12.16

C. "Though there is a small theoretical risk of thermal injury, this exam is rapidly conducted, minimizing the risk."
D. "About as much as life risk of deep penetrating, ionizing radiation."

25. A 73-year-old male with a history of diabetes and coronary artery disease presents with sudden onset of painless vision loss of the right eye since yesterday. He denies any trauma or associated eye pain. Exam was pertinent for visual acuity OD to gross hand motion and OS 20/25 with a normal fluorescein exam and intraocular pressure. Fundoscopic exam was normal in the left and on the right reveals a prominent fovea. Bedside ultrasound reveals the image in Figure 12.17. What is the next step in management?

Figure 12.17

A. Laser surgery (photocoagulation).
B. IV steroids and optimize management of risk factors.
C. Ocular-digital massage, emergent ophthalmology consult with possible hyperbaric chamber treatment.
D. Ophthalmology consult for laser iridotomy.

26. A 68-year-old non-English-speaking female presents with right eye itching and redness for 1 day. The family explains that several household members have the same symptoms. However, the patient is concerned about involvement of recent eye surgery she had 1 month prior to correct her vision. The family is unable to provide any further information regarding the surgery. While waiting for the interpreter, you begin your examination. Slit lamp exam of the right eye reveals conjunctival injection while the left eye shows normal conjunctiva and an opaque lens. Visual acuity is 20/20 in the right and 20/100 in the left. Fundus is normal on the right and unable to be visualized on the left. You perform an

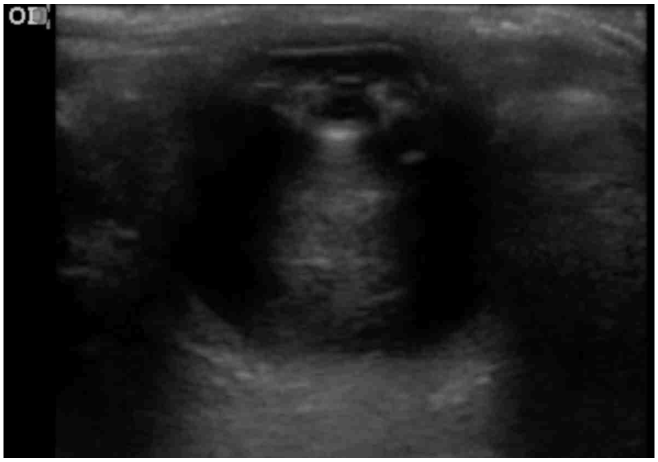

Figure 12.18

ultrasound (see Figure 12.18 and Video 12.6), which reveals which of the following?

A. Artificial lens
B. Lens dislocation
C. Cataract
D. Vitreous hemorrhage

27. A 65-year-old female recently diagnosed with choroidal melanoma presents with blurred vision and floaters in the right eye for 1 week. While the choroidal melanoma was noticed incidentally 3 months prior, she had never had visual symptoms until now. Physical exam shows no gross abnormalities. Visual acuity is OD-20/200, OS-20/20. Visual fields reveal a deficit in the left field in the

Figure 12.19

right eye and no deficits in the left eye. Her slit lamp exam appears normal. Fundoscopic exam reveals a brownish round spot just lateral to the macula with the appearance of whitish folds adjacent to it. To better assess the posterior chamber, you perform the ocular ultrasound shown in Figure 12.19 and Video 12.7. Which of the following most likely caused her acute vision change?

A. Exudative retinal detachment
B. Central retinal artery occlusion
C. Rhegmatogenous retinal detachment
D. Central retinal vein occlusion

ANSWERS

1. EXPLANATION

C. Linear 7.5-10 MHz, small parts, B-mode. POCUS ocular examination requires a high-frequency linear-array transducer with an emitted frequency at least equal or superior to 7.5 MHz for optimal visualization of ocular structures. Other transducers with similarly high frequency may be substituted if linear is not readily available such as hockey stick and endocavitary transducers. Presets are display settings that the manufacturer has set on a particular machine to optimally display certain types of structures. In this scenario, a user may utilize ocular or small parts. Presets are also associated with certain calculation capabilities. For example, to calculate fetal heart tones, the user must select obstetric exam preset. It is important to note that presets are set by the manufacturer and may vary between machines. Often, despite using the correctly designated preset, further adjustment by the user may be necessary, such as with gain. Additionally, optimal depth to capture the area of interest (the globe and posterior structures if warranted) is typically around 5 to 7 cm. Modes are generally consistent across machines and dictate what information the machine is collecting and being displayed. B-scan (gray scale) is the mode displaying the 2-dimensional image in which the majority of ultrasound is performed. On some machines, B-mode is instead labeled 2D. While in B-scan mode, the operator should scan in transverse sections to identify the appropriate anatomy and evaluate for pathology. Doppler mode displays further information regarding flow, which requires higher output of ultrasound signals, which are absorbed by the tissue being imaged. Use of Doppler should be limited because of the theoretical harm of heat applied to the tissue from higher thermal and mechanical index, based on the “as low as reasonably achievable” (ALARA) principle. Therefore, C is the correct answer. Choice A is incorrect because the frequency is too low, the preset should not be vascular, and Doppler is not necessary thus should not be used based on the ALARA principle. Choice B is incorrect because the frequency is too low and M-mode is not necessary. Choice D is incorrect because while an endocavitary probe can be used, it is not ideal, a vascular setting is not optimal, and Doppler is not necessary.

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AIUM Official Statement. As low as reasonably achievable (ALARA) principle. http://www.aium.org/officialStatements/39.

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Keywords/Tags: Ocular, retinal detachment

2. EXPLANATION

B. Anchoring fingers on patient’s temporal or brow bone. This case illustrates a vasovagal episode in the patient induced by excessive ocular pressure which in turn triggered the oculocardiac reflex. The oculocardiac reflex occurs due to parasympathetic stimulation mediated by nerve connections between the ophthalmic branch of the trigeminal cranial nerve via the ciliary ganglion and the vagus nerve. The symptoms produced may include nausea, vomiting, dizziness, pallor, diaphoresis, and bradycardia and may progress to syncope. Neonates and children are particularly susceptible though it can occur in all ages. Though rare, patients have been known to progress to cardiac arrest. Thus it is important to avoid excessive pressure of the transducer to the globe by always anchoring the scanning hand on the nasal bridge, brow bone, or maxilla while scanning, thus avoiding excessive pressure of the transducer to the globe, as described in choice B (Figure 12.20). Choice A is incorrect as gel is unlikely to produce a rapid vasovagal episode, though local contact dermatitis or allergic reaction is possible. Choice C is also incorrect; while it could be argued that anesthetic diminishes the eye pain that could produce a vasovagal episode, the patient reported no discomfort prior to scanning and ocular anesthetic only affects the cornea, not the globe. Choice D is incorrect as well, as a mydriatic (substance causing pupillary dilation) produces

Figure 12.20 **Anchoring fingers on patient’s nasal bone and temporal bone (red *).**

antimuscarinic or alpha1 agonist symptoms but is unlikely to counteract a vasovagal episode nor be administered in high enough concentrations to produce systemic symptoms.

Learning Points: Excessive pressure on the globe can cause a vagal episode via the oculocardiac reflex.

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Keywords/Tags: Anchoring, oculocardiac reflex, vasovagal, ocular trauma

3. EXPLANATION

B. 2, 1, 4, 3. Ocular ultrasound is a quick, noninvasive test used to assess ocular anatomy and pathology. Make the patient comfortable by having his or her lay supine or semi-recumbent position. Arrange the ultrasound machine to be able to face the patient and ultrasound screen simultaneously. Use the patient's forehead or nasal bridge to anchor and stabilize the ultrasound transducer probe and minimize pressure to the eye, which can be crucial when evaluating for certain pathology such as globe injury. Though not crucial to the study, applying a sterile cover (i.e., Tegaderm) over the closed eyelid will allow for easy cleanup and removal as well as less irritation of the eyes from the gel (Figure 12.21). To optimize image acquisition, apply abundant amount of gel (preferably chilled) to allow the transducer to get full contact with the eye via the medium. Perform the exam in B-mode and adjust the focus during the exam. The gain should be decreased when evaluating for structural integrity and optic nerve sheath and increased when assessing for posterior chamber pathology such as detachment or hemorrhage.

Figure 12.21 **Tegaderm placed over eyelid with copious amount of gel.**

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Roth KR, Gafni-Pappas G. Unique method of ocular ultrasound using transparent dressings. *J Emerg Med*. 2011;40(6):658–660.

Keywords/Tags: Ocular, knobology, acquisition

4. EXPLANATION

B. Cataracts. Cataracts are opacification or abnormal thickening of the lens most commonly due to deposition of proteinaceous material. Treatment is surgical removal and replacement of the lens. While detection of cataracts by ultrasound has similarly high sensitivity and specificity compared to physical exam, it has the added benefit of allowing the user to assess the posterior chamber, which is obscured by the opaque lens. Patients suffering from vision loss due to cataracts often have comorbidities associated with posterior chamber abnormalities such as with retinal detachment (RD) or vitreous hemorrhage. In such cases where direct visualization of posterior chamber or retrobulbar structures is limited, ultrasound can be integral to the evaluation and operative planning. Choice A is incorrect as the video shows the lens in a normal location, anteriorly situated in the posterior chamber immediately posterior to the iris and pupil. Choices C and D are incorrect as there are no other echogenic structures seen in the posterior chamber.

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Salman A, Parmar P, Vanila CG, Thomas PA, Jesudasan CAN. Is ultrasonography essential before surgery in eyes with advanced cataracts? *J Postgrad Med*. 2006;52(1):19–22.

Keywords/Tags: Lens, cataract, posterior chamber, retrobulbar

5. EXPLANATION

C. Assess for acute glaucoma. Sonographic ocular exam is performed for acute visual changes to evaluate for retinal

versus vitreous detachment, vitreous hemorrhage, or intraocular foreign body. In the setting of trauma, bedside ultrasound is used for lens dislocation or retrobulbar hematoma, or even to assess for pupillary constriction. It can also be used for evaluating extraocular eye movement when direct visualization is limited due to facial trauma and swelling or visual axis obstruction, such as hyphema, hypopion, hemorrhage, or cataracts. Ultrasound may be used to evaluate for globe rupture; however, extreme care must be taken with ample gel to ensure no additional pressure is exerted on the globe. Although controversial, abnormal measurement of optic nerve sheath can provide information related to elevated intracranial pressure (ICP). There is currently no clinical application for use of ultrasound in the diagnostic evaluation of acute glaucoma. However, there are therapeutic uses of ultrasound for glaucoma (Schwartz et al. 2014).

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Keywords/Tags: Ocular, clinical indications

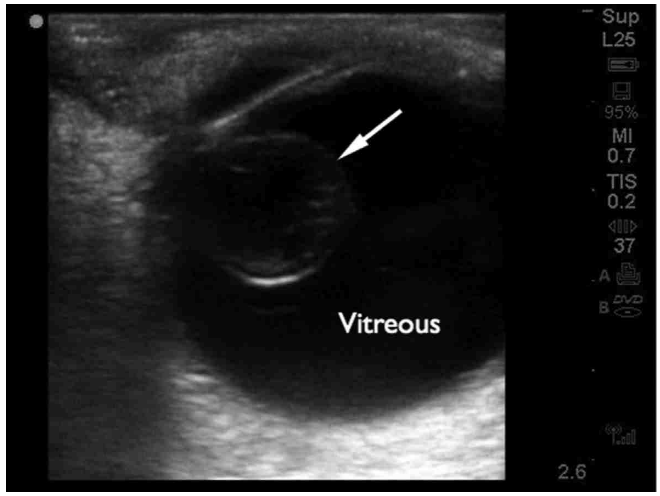

Figure 12.22 **Lens dislocation (arrow).** Adapted from Figure 3 of Frasure SE, Saul T, Lewiss RE. Bedside ultrasound diagnosis of vitreous hemorrhage and traumatic lens dislocation. Am *J Emerg Med*. 2013;31(6):1002.e1–e2

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Jarrett WH II. Dislocation of the lens: a study of 166 hospitalized cases. *Arch Ophthalmol*. 1967;78(3):289–296.

Keywords/Tags: Ocular, anatomy, lens subluxation

6. EXPLANATION

C. In the case of connective tissue disorder, such as Marfan syndrome, is often associated with lens subluxation. It can also occur in the setting of trauma. The lens, a curved hyperechoic structure, can be displaced either anteriorly or posteriorly from its normal anatomical location (Figure 12.22). It is more apparent with eye movement. Choice A identifies the iris, which is an echogenic linear structure that extends from the peripheral globe to the lens. The iris is responsible for the amount of light that reaches the retina and therefore accounts for the pupillary response. The anterior chamber, noted in choice B, is a spherical structure between the cornea and the lens that is fluid-filled with aqueous humor. Choice D is the cornea, which is made up of primarily transparent stromal tissue that helps to conduct and focus light. Of the four labeled structures, only the lens can dislocate.

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7. EXPLANATION

A. Pupil, lens, vitreous, optic nerve. The pupil, lens, vitreous chamber, iris, and optic nerve can be identified on ultrasound (Figure 12.23). The eye is an ideal structure for ultrasound since it is filled with fluid, which acts as the perfect acoustic window. On ultrasound the eye appears as a circular hypoechoic structure. When gel is properly placed on the eye without interfering air bubbles, even the superficial portions of the eye can be seen with great detail. Directly deep to the eyelid is the thin hypoechoic layer of the cornea, which serves as the anterior border of the anterior chamber. The anechoic fluid within the anterior chamber is bordered posteriorly by the iris and anterior reflection of the lens capsule. Just deep to the iris on either side are the ciliary bodies extending from the peripheral globe toward the lens. The normal lens is anechoic except for the posterior aspect of the lens seen as a curved line. However, the lens can become echogenic with significant debris or thickening such as in cataracts. The normal vitreous chamber is filled with anechoic fluid but in certain disease processes may contain echogenic debris. The posterior border of the vitreous on ultrasound is the retina, which sonographically

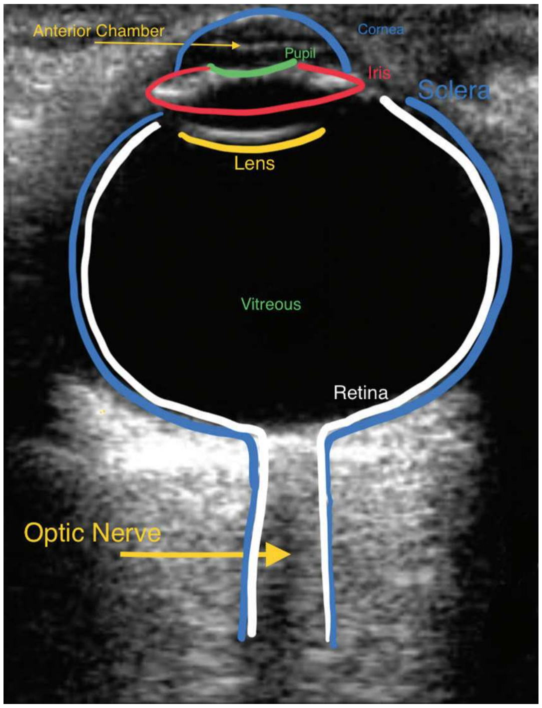

Figure 12.23 **Ocular anatomy of normal structures.**

cannot be differentiated from the other choroidal layers except when detached. The optic nerve is visible posteriorly in the retrobulbar region as a hypoechoic linear structure extending away from globe.

REFERENCE

Kilker BA, Holst JM, Hoffmann B. Bedside ocular ultrasound in the emergency department. *Eur J Emerg Med*. 2014;21(4):246–253.

Keywords/Tags: Ocular anatomy

8. EXPLANATION

B. Anterior chamber collapse. Sonographic findings of globe rupture consist of the decrease in volume of the globe, anterior chamber collapse, irregular contour, and integrity and buckling of the sclera (Figure 12.24a). The classical finding of the "washing machine" sign (also known as snow globe appearance) is seen in vitreous hemorrhage during a dynamic eye exam as you see the swirling of hemorrhage in the posterior chamber (Figure 12.24b, Video 12.8); therefore choice A is incorrect. Choice C is incorrect since the bedside ultrasound finding of a deformation of a posterior globe is known as the "guitar pick" sign (Figure 12.24c), seen in cases of retrobulbar hematoma. Other findings of globe rupture may also include anterior chamber collapse instead of expansion, so choice D is incorrect.

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Keywords/Tags: Ocular, globe rupture

9. EXPLANATION

D. Place eye shield, update tetanus, and emergent ophthalmology consult. Traumatic globe rupture is

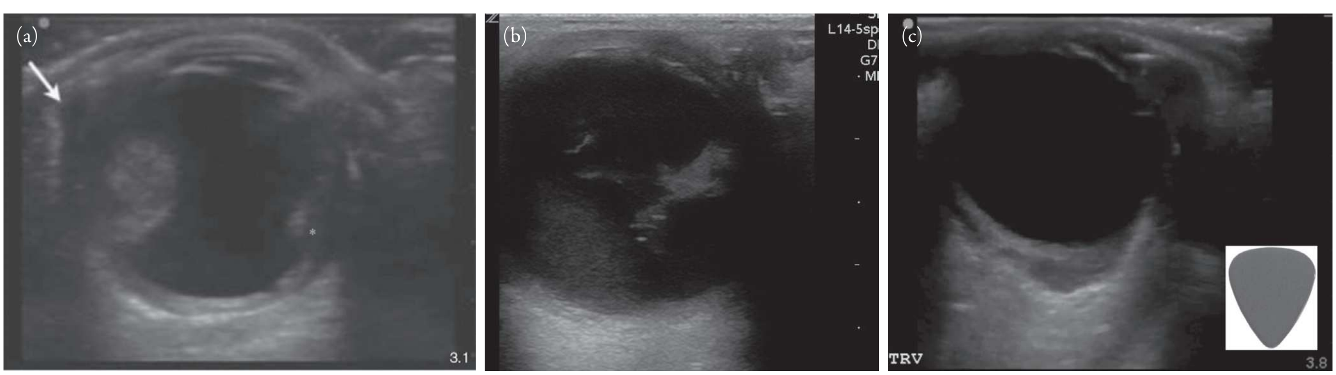

Figure 12.24 (a) **Globe rupture with flattening of the anterior chamber, loss of spherical shape of globe, internal echoes, scleral buckling (white arrow) and retinal hemorrhage (*).** Adapted from Figure 2 of Kilker BA, Holst JM, Hoffmann B. Bedside ocular ultrasound in the emergency department. *Eur J Emerg Med.* 2014;21(4):246–253. doi:10.1097/MEJ.0000000000000070. (b) **Vitreous hemorrhage with "washing machine" sign.** See Video 12.2. (c) **Retrobulbar hemorrhage with "guitar pick" sign and deformation of the posterior globe.**

considered a true ocular emergency, therefore immediate ophthalmology consult is warranted to prevent permanent vision loss. Sonographic findings of globe rupture include irregular contour and reduced volume of the globe along with distorted integrity. When performing the exam, the ultrasound operator must use a copious amount of chilled gel to avoid excessive pressure over the globe and expulsion of contents. In addition, you may also see collapsed anterior chamber and buckling of the sclera. In this patient, the image shows reduced ocular volume, appears irregular, and has hyperechoic debris in the posterior chamber that likely represent clots (Figure 12.5, Video 12.2). Aside from immediate ophthalmology consult for definitive management, treatment includes placing a rigid eye shield to minimize further increase in intraocular pressure, updating tetanus, and administering prophylactic antibiotics (Bord 2007). Choice A refers to treatment of a retrobulbar hematoma and choice B to treatment of RD, so they are incorrect. Choice C is incorrect since it describes treatment for traumatic iritis. Currently there is no role for ultrasound in the diagnosis of traumatic iritis, so it remains a clinical diagnosis with findings of "cell and flare" on slit lamp exam.

There are no absolute contraindications for ocular sonography except delay in definitive care and management. However, relative contraindications exist in cases of open ocular trauma, suspected global rupture, or retrobulbar hematoma. As mentioned earlier, the initial step in management of globe rupture involves prevention of further pressure over the globe that would cause protrusion of contents where the use of ultrasound is controversial, causing potential unnecessary pressure over the eyeball and possibly worsening the condition. For that reason, the majority of experts favor not using ultrasound for suspected globe rupture or, if used, using a copious amount of gel, a gel block, or an intravenous (IV) fluid bag to prevent exerting any pressure on the globe (Chandra et al. 2009).

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Keywords/Tags: Ocular, trauma, globe rupture

10. EXPLANATION

C. Lens dislocation. Dislocation of the lens is easily visualized on ultrasound. Dislocation may be complete or a partial subluxation. With complete dislocation the lens will be out of the usual position and untethered, usually settling in the posterior chamber (Figure 12.6). In subluxation, the lens may initially appear normal but will move independently on kinetic exam (eye movement during real time ultrasound) (Figure 12.25). Lens dislocations usually occur as a result of trauma or are associated with connective tissue diseases. Choice A is incorrect as there does not appear to be a linear structure floating in the posterior chamber as would be the case in RD. Choice B is incorrect as there appears to be no prominence of the optic disc as in papilledema. Choice D is incorrect as there is no deviation in the spherical shape of the globe, as would be the case with retrobulbar hematoma where the globe shape begins to approximate that of a guitar pick.

Figure 12.25 **Lens subluxation.**

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Ojaghi Haghighi SH, Morteza Begi HR, Sorkhabi R, et al. Diagnostic accuracy of ultrasound in detection of traumatic lens dislocation. *Emerg* (Tehran). 2014;2(3):121–124.

Keywords/Tags: Ocular anatomy, lens dislocation, lens subluxation

11. EXPLANATION

A. Retinal detachment. RDs are important to recognize as early intervention can prevent significant vision loss.

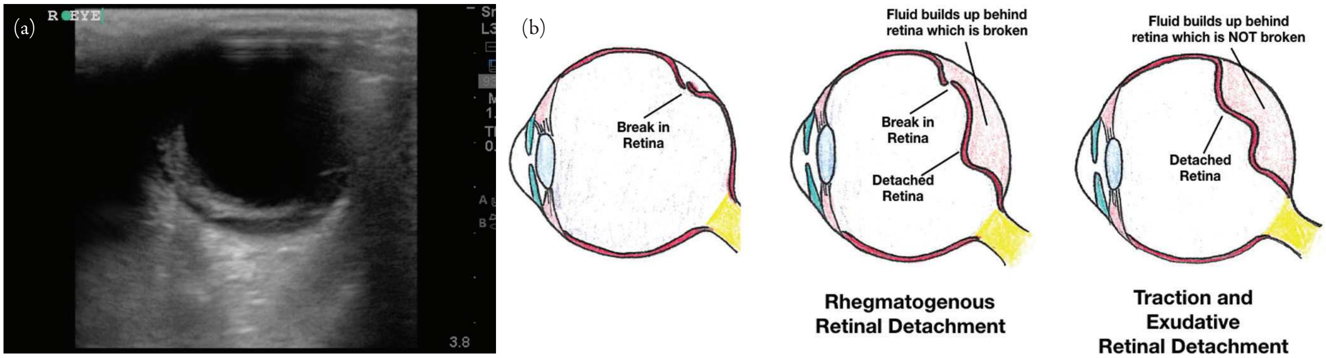

Figure 12.26 (a) **Exudative retinal detachment with echogenic material in the subretinal space.** (b) **Classification of retinal detachments.** Adapted from: https://patient.info/health/visual-problems/retinal-detachment.

Normally, the retina is attached anteriorly to the ora serrata and posteriorly to the optic nerve. It is adhered anteriorly to the choroid of the eye. There are three different types of RDs: tractional, retinal tears (aka rhegmatogenous), and exudative. Rhegmatogenous RDs are due to round holes, tears, or breaks in the retina and subsequent filling of the subretinal space with vitreous fluid. It is the most common cause of RD (D'Amico 2008). Tractional RDs occur via centripetal mechanical forces on the retina, usually mediated by fibrotic tissue resulting from previous hemorrhage, injury, surgery, infection, or inflammation. Correction of tractional RD requires disengaging scar tissue from the retinal surface, and vision outcomes are often very poor. Exudative RD (Figure 12.26a, Video 12.9) results from the accumulation of serous and/ or hemorrhagic fluid in the subretinal space because of hydrostatic factors (e.g., severe acute hypertension), inflammation (e.g., sarcoid uveitis), or neoplastic effusions (Amer et al. 2017). Exudative RDs generally resolve with successful treatment of the underlying disease, and visual recovery is often excellent. The main difference between rhegmatogenous RD and the other 2 types is that rhegmatogenous RDs have a tear in the retina whereas tractional and exudative do not (Gariano 2004; Figure 12.26b).

Tractional and exudative RDs may not be detected on ultrasound early on. If a clinical story is suspicious, RD should still be considered and an ophthalmology consult should be obtained for indirect fundoscopy. Sonographic findings of RD display a thin, hyperechoic linear membrane floating in the posterior chamber of the eye but tethered to the optic disc. Vitreous detachments, on the other hand, will have nontethered haphazard movement. RDs also typically can be seen with normal gain while vitreous detachments (VDs) often require over gain for accurate assessment. The urgency of ophthalmology evaluation and surgical repair depends largely on the relation of the retina to the macula. The macula is directly lateral to the optic nerve sheath. If the retina is still attached to the macula with only minimally impaired vision (aka "mac on"), the patient should receive emergent ophthalmology consultation and surgery to prevent further detachment from the macula. This can significantly preserve a patient's vision. Conversely, retina detachments that involve the macula typically present with more drastic impaired vision, and surgical intervention is less likely to be beneficial, especially if duration is greater than 7 days, with the best outcomes associated with duration less than 3 days (Van Bussel et al. 2014). Choices B and C are incorrect as vitreous detachment and hemorrhage are not tethered to the optic nerve as demonstrated in the video. Choice D is incorrect: central retinal vein occlusion (CVRO) and central retinal artery occlusion (CRAO) typically require Doppler to assess for vascular flow deficits or ultrasound is used to visualize emboli in the retrobulbar space.

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Keywords/Tags: Ocular, retinal detachment

12. EXPLANATION

A. Increase gain. When the gain is increased, the pathology is much more easily seen. The diagnosis in question is vitreous hemorrhage or bleeding into the vitreous cavity, due to trauma, microvascular disease, and rarely subarachnoid

hemorrhage. The hemorrhage can be seen on fundoscopic exam. On ultrasound it appears as echogenic material floating in the anechoic posterior chamber that swirls haphazardly with movement of the globe. This characteristic movement requires performance of a kinetic exam, in which the patient will move the eye during the ultrasound by looking left/right or up/down under the closed eyelid (Rubano et al. 2010). With the kinetic exam, swirling blood will move with the motion of the globe, while artifact will appear static. The echogenicity of the hemorrhage is directly correlated with its density. Thus in acute bleeds where there is minimal or noncoagulated blood, hemorrhage may not be detected with normal gain. Increasing gain and performing a kinetic exam will improve the sensitivity of the study and avoid false negatives (Figure 12.27, Video 12.10).

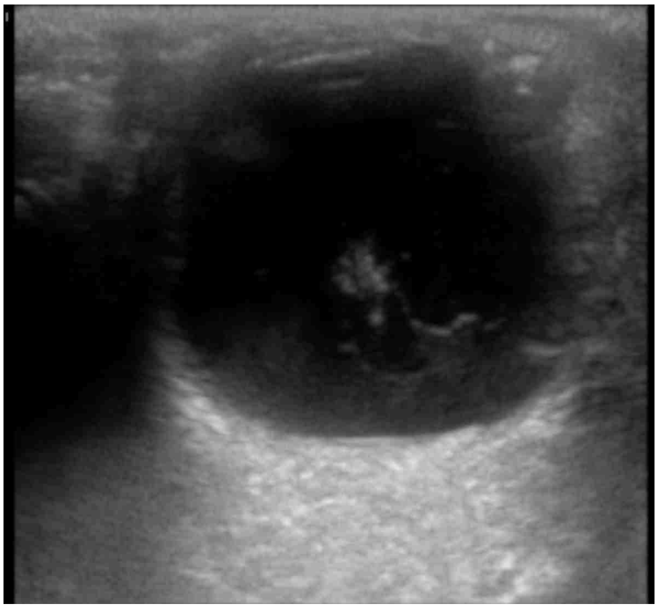

Figure 12.27 **Visualization of vitreous hemorrhage with increase in gain.**

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Rubano EJ, Jackson KA, Stone MB. Kinetic echography in the evaluation of retinal detachment. *Acad Emerg Med*. 2010;17(6):e46–e47.

Keywords/Tags: Vitreous hemorrhage, gain

13. EXPLANATION

C. Vitreous detachment. VDs often present similarly to RDs with vision loss, floaters, and flashers (photopsia). However, unlike RDs, which are anchored to the optic nerve posteriorly and the ora serrata anteriorly (Figure 12.28a, Video 12.11), VDs are untethered to any other structure in the posterior chamber and thus have more freedom of movement (Figure 12.28b). A classic VD will "float" above the optic nerve, while a classic RD will be attached to the optic nerve. There is, however, a spectrum of both RDs and VDs that do not involve the optic nerve, so there should be caution in differentiating the 2 entities, unless there is a clear disengagement or attachment to the optic nerve. Also VDs are associated with hemorrhage, which produces the characteristic erratic swirling on kinetic exam appearing similar to clothes swirling around in a washing machine. Choice A is incorrect because the lens is in the proper anterior location in the vitreous and not settling near the retina as would be the case in lens dislocation. Choice B is incorrect as the optic disc appears flat and smooth against the contours of the retina instead of raised as would be seen with papilledema. Choice D is incorrect as discussed in the explanation earlier because RDs are tethered to the optic nerve.

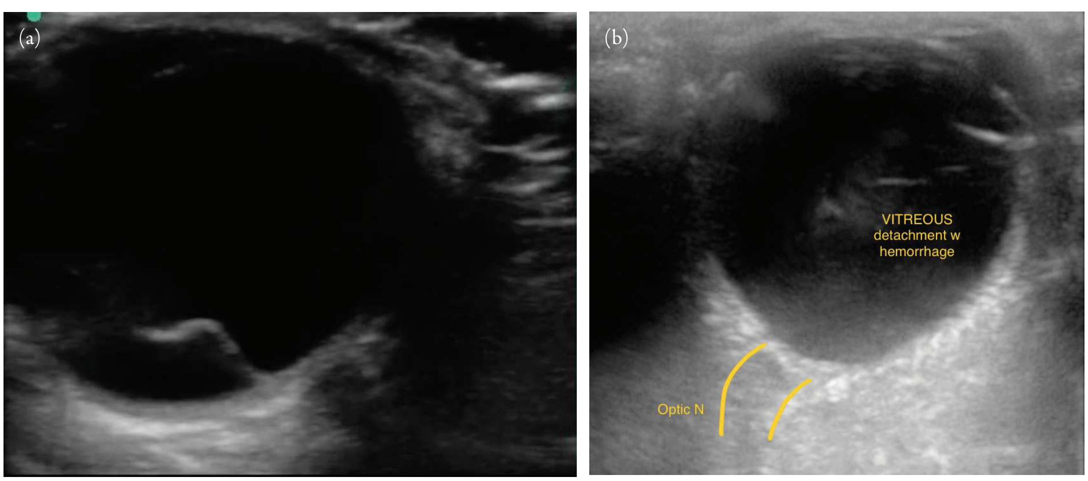

Figure 12.28 (a) **Retinal detachment with anchoring to the optic nerve.** (b) **Vitreous hemorrhage and detachment with no attachment to optic nerve.**

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Keywords/Tags: Vitreous detachment, ocular anatomy, vitreous hemorrhage

14. EXPLANATION

D. Greater than 5 mm measured at 3 mm posterior to globe. The optic nerve sheath should be measured at the dark shadow of the optic nerve sheath noted posterior to the retina in a transverse plane. The perineural sheath is bathed in the continuous cerebrospinal fluid (CSF) surrounding the brain therefore an increase in ONSD is an indirect measurement for increase in ICP. Measurement of ONSD is measured by obtaining 3 mm vertical to posterior retina, followed by obtaining the horizontal distance across the optic sheath shadow (Figure 12.29). Because the optic nerve is not completely cylindrical, it is important to obtain at least 2 to 3 orthogonal measurements (i.e., with the probe in sagittal and transverse orientation) and to use the mean diameter. An ONSD is considered abnormal if greater than 5 mm in patients with altered mental status or other symptoms concerning for elevated ICP. A meta-analysis done by Dubourg et al. in 2011 to evaluate the accuracy of ONSD to detect of increased ICP showed a pooled sensitivity and specificity of 0.90 and 0.85. Therefore, the use of ultrasound of ONSD can be a noninvasive rapid measurement for detecting elevated ICP as well as monitor ICP serially over time.

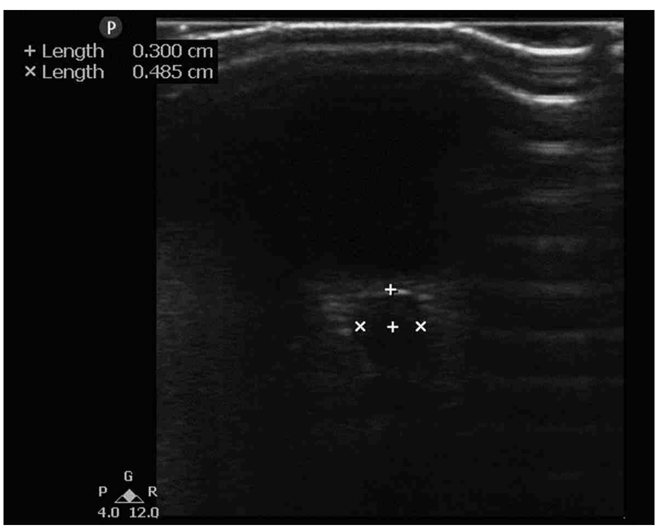

Figure 12.29 **Measurement of optic nerve sheath diameter**. It is measured by obtaining 3 mm vertical to posterior retina and then measure the horizontal distance across the optic sheath shadow.

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Keywords/Tags: Ocular, papilledema, intracranial pressure, enlarged optic nerve sheath diameter, idiopathic intracranial hypertension

15. EXPLANATION

C. Lumbar puncture with CSF drainage. The patient in question presents with papilledema consistent with IIH. The initial ultrasound displays papilledema with a rounded hyperechoic mass (asterisk) arising from the optic disc and protruding into the posterior chamber (Figure 12.10a). Measurement of the ONSD was 7.1 mm, which is consistent with increased ICP (Figure 12.10b). IIH is the most likely diagnosis given new-onset papilledema with normal head CT. The next best step is to perform a therapeutic lumbar puncture to reduce the ICP. Also, outpatient neurologic and ophthalmologic follow-up must be ensured. Choice A is incorrect because she does not have an intracranial etiology requiring decompression. Choice B is incorrect because the next best step in management is lumbar puncture, though the patient will need urgent follow-up with neurology as an outpatient. Choice D is incorrect because the patient does not have a retrobulbar hemorrhage. Serial ultrasounds have been demonstrated in many studies to be an accurate and noninvasive means of monitoring ICP (Maissan et al. 2015).

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Stone MB. Ultrasound diagnosis of papilledema and increased intracranial pressure in pseudotumor cerebri. *Am J Emerg Med.* 2009;27(3):e1–e376.

Keywords/Tags: Elevated ICP, Increased ONSD, ICP monitoring

16. EXPLANATION

B. Color Doppler flow to measure changes in retrobulbar vascular dynamics and optic nerve diameter; unilaterally increased ONSD. The optic nerve is made of 3 layers: pia, arachnoid, and dura mater with a thin layer of CSF traversing layers. In MS, the inflammatory response from cytokines attracting fluid into these layers is thought to cause the increased ONSD. As the inflammation continues, axonal conduction is impeded, causing visual impairment. A similar effect is seen in the optic nerves for processes exerting mass effect and elevating ICP such as in benign intracranial hypertension though, in these processes, it is a noninflammatory edema.

The dilation of the optic nerve in both these processes can be seen on ultrasound. An ONSD is measured 3 mm distal to the posterior retina and considered abnormal if greater than 5 mm (Figure 12.30a). Unilaterally increased ONSD favors a diagnosis of optic neuritis whereas bilateral optic nerve dilation is more consistent with elevated ICP (Lochner et al. 2017). However, in conditions where both optic nerves are inflamed, there may be bilaterally increased ONSD.

In addition, some studies have helped to further differentiate the 2 processes by noting increased retrobulbar vascular supply secondary to inflammatory changes in optic neuritis (Hradílek et al. 2009). This can be seen with spectral Doppler with elevated ophthalmic artery peak systolic

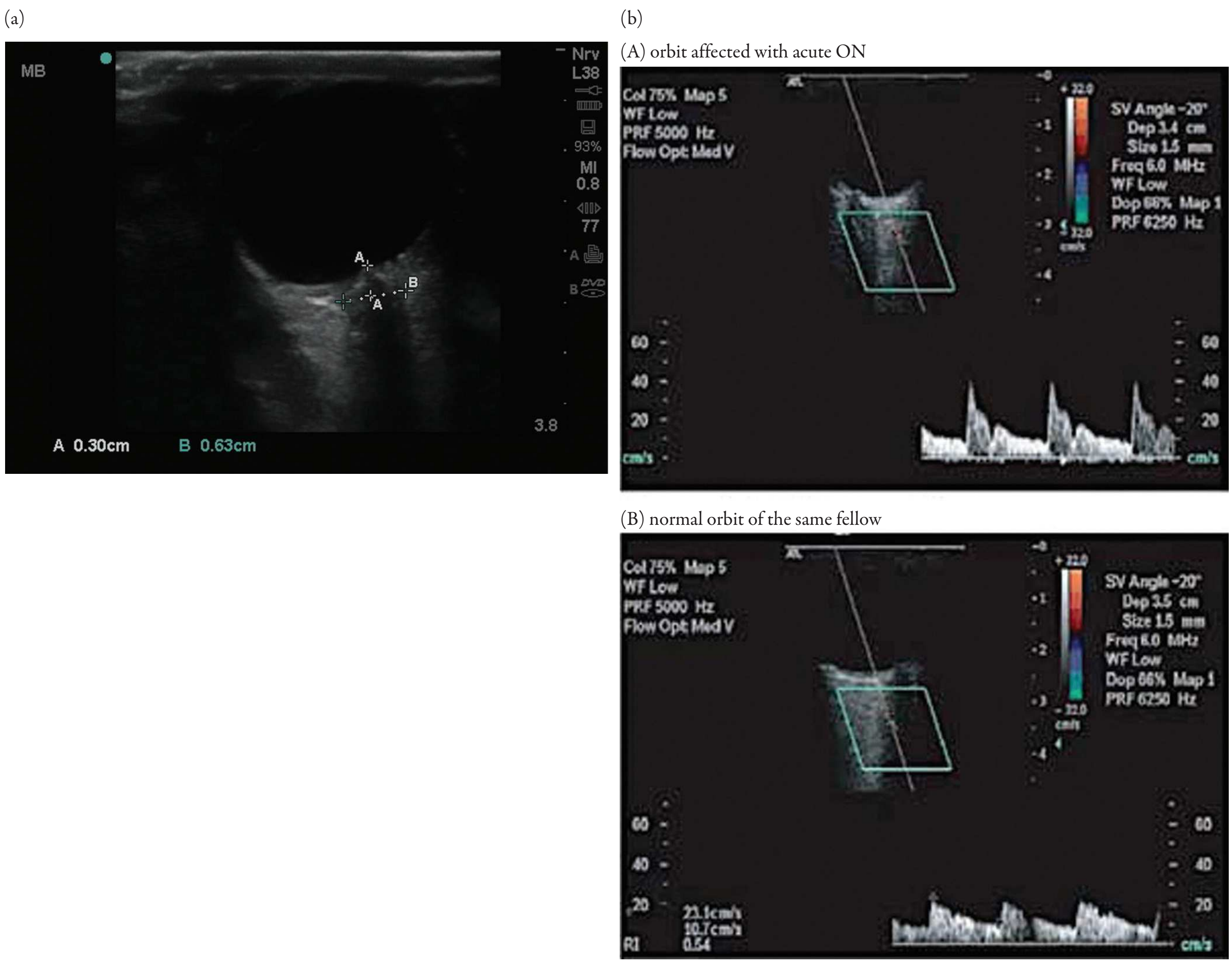

Figure 12.30 (a) **Elevated optic nerve sheath diameter of 6.3 mm.** (b) (A) Optic neuritis with significantly elevated peak systolic velocity and resistive index. (B) Contralateral normal eye of same patient with normal peak systolic velocity and resistive index. Adapted from Figure 1 of Hradílek P, Stourac P, Bar M, Zapletalová O, Školoudík D. Colour Doppler imaging evaluation of blood flow parameters in the ophthalmic artery in acute and chronic phases of optic neuritis in multiple sclerosis. *Acta Ophthalmol.* 2009;87(1):65–70. doi:10.1111/j.1755-3768.2008.01195.x.

velocities and resistive indices (Figure 12.30b). However, further studies are warranted to accurately determine abnormal cutoff values.

Choice A is incorrect because there should be unilateral increase in ONSD and M-mode is not useful for optic neuritis. Choice C is incorrect because 2D fractional shortening is a method for predicting ejection fraction of the heart; it has no correlation with optic neuritis. Choice D is incorrect because optic nerve length is not a useful parameter for evaluating for optic neuritis.

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Lochner P, Leone MA, Fassbender K, et al. Transorbital sonography and visual outcome for the diagnosis and monitoring of optic neuritis. *J Neuroimaging*. 2017;27(1):92–96.

Keywords/Tags: Optic neuritis, ONSD, color Doppler

17. EXPLANATION

D. Figure 12.11d. The clinical presentation is concerning for atraumatic subarachnoid hemorrhage, most often due to aneurysmal rupture. In such cases, you can evaluate for increased ICP indirectly by looking for papilledema. An ONSD is considered abnormal if greater than 5 mm in adults and 4.5 mm in children. The ONSD is measured by obtaining 3 mm vertical to the posterior retina and then across horizontally at the optic sheath shadow. A vertical distance of 3 mm behind the globe is used because that is where ultrasound contrast is the greatest and the results are more reproducible. The image in choice A has evidence of abnormal optic sheath nerve diameter in comparison to choice B, which is within normal limits. Choice C shows incorrect optic sheath measurement. Choice D shows evidence of actual bulging of the optic disk, which is the most specific finding for papilledema (Stone 2009).

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Tayal VS, Neulander M, Norton HJ, Foster T, Saunders T, Blaivas M. Emergency department sonographic measurement of optic nerve sheath diameter to detect findings of increased intracranial pressure in adult head injury patients. *Ann Emerg Med*. 2007;49(4):508–514.

Keywords/Tags: Ocular, papilledema, intracranial pressure, enlarged optic nerve sheath diameter

18. EXPLANATION

C. Figure 12.12c. The optimal scan technique to assess the optic nerve is to use the linear probe, not the cardiac probe as illustrated in choice D. There should be a copious amount of ultrasound gel placed on the eye, with or without a clear film barrier, to minimize pressure on the globe. The probe is then placed in transverse orientation on the temporal aspect of the eyelid and directed medially toward the posterior nasal bridge. This allows the sound waves emitted from the transducer to traverse along the natural course of the optic nerve as it angles toward the optic chiasm (Figure 12.31). The probe is then fanned to capture the clearest image of the optic nerve and measured at its widest point. Due to the angulation of the nerve, several measurements should be taken and averaged to get the most accurate value. Choice A is incorrect as the transducer is placed medially and directed temporally. Choice B is not the best initial

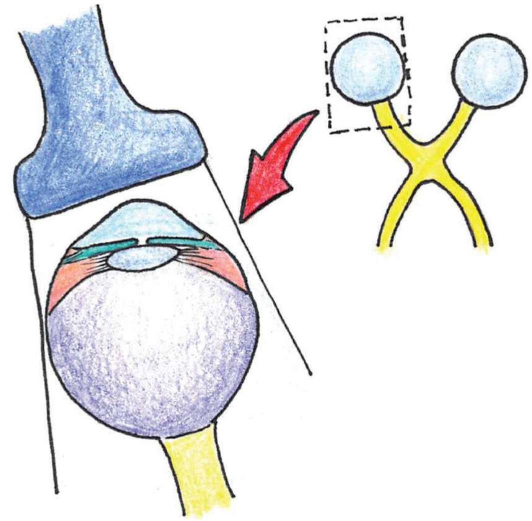

Figure 12.31 **Correct positioning of transducer to evaluate and measure the optic nerve sheath diameter.** Adapted from Figure 2 of Tayal VS, Neulander M, Norton HJ, Foster T, Saunders T, Blaivas M. Emergency department sonographic measurement of optic nerve sheath diameter to detect findings of increased intracranial pressure in adult head injury patients. *Ann Emerg Med*. 2007;49(4):508–514. doi:10.1016/j.annemergmed.2006.06.040.

plane to use (longitudinal), but it can be used to obtain a subsequent measurement in the orthogonal plane for calculating a mean diameter.

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Keywords/Tags: Elevated ICP, Increased ONSD

19. EXPLANATION

D. I. Ophthalmic artery, II. ciliary arteries, III. central retinal artery. Anatomically, the first branch off the internal carotid is the ophthalmic artery. As this artery approaches the eye, it splits into the posterior ciliary arteries and the central retinal arteries (Figure 12.32a). The posterior ciliary arteries travel lateral to the optic nerve to perfuse the peripheral retina. The central retinal artery travels within the optic nerve to perfuse the central retina. Consequently, when there is CRAO, the ciliary arteries can supply collateral circulation and can be seen with color

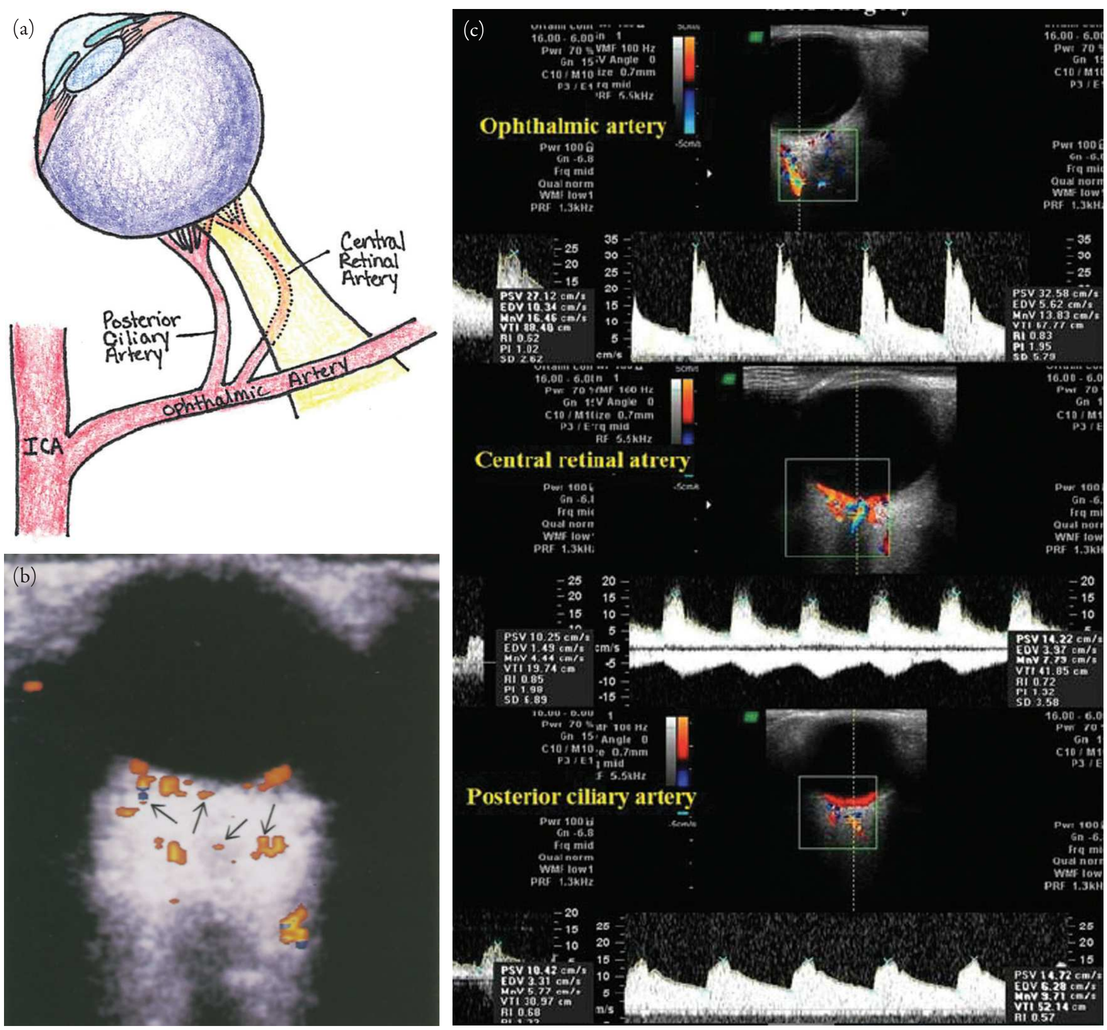

Figure 12.32 (a) **Blood supply to the eye.** The ophthalmic artery branches off of the internal carotid artery and further divides into the posterior ciliary artery and central retinal artery. (b) **The color Doppler image is provided for a patient with central retinal artery occlusion on whom no flow was detectable within the optic nerve.** Posterior ciliary arteries are still detectable (arrows). Adapted from Figure 8 of Williamson TH, Harris A. Color Doppler ultrasound imaging of the eye and orbit. *Surv Ophthalmol.* 1996;40(4):255–267. (c) **Doppler patterns of arterial supply to the eye.** the ophthalmic artery has a similar Doppler pattern to the internal carotid artery with a dicrotic notch with sharp peaks. The central retinal artery is located closer to the retina within the distal optic nerve and has a Doppler pattern consistent with rounded peaks. Posterior ciliary arteries are located lateral to the optic nerve near the retina, and also have rounded peak waveforms.

Doppler (Figure 12.32b). These arteries can be identified by their location and Doppler patterns on ocular ultrasound. The vessels each have distinct Doppler signal patterns (Figure 12.32c). Because it branches directly off the internal carotid artery, the ophthalmic artery has a similar Doppler pattern, a dicrotic notch with sharp peaks. The central retinal artery is located closer to the retina within the distal optic nerve and has a Doppler pattern consistent with rounded peaks. Posterior ciliary arteries are located lateral to the optic nerve near the retina and also have rounded peak waveforms.

It is important to note the following points about CRAO:

- Branches of the central retinal artery may be occluded in branch retinal artery occlusion (BRAO), so ultrasound findings may be limited, unless the branch artery is identified and sampled.
- There may be diminished flow on pulsed wave Doppler and color Doppler for the affected side in CRAO, but not necessarily complete absence of flow.
- CRAO typically occurs due to emboli from either a cardioembolic process (e.g., atrial fibrillation) or carotid artery plaque or dissection, so adjunct imaging should be considered if there is a high suspicion for CRAO.

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Keywords/Tags: Central retinal artery occlusion, ocular vascular territories, central retinal artery, ophthalmic artery, ciliary arteries

20. EXPLANATION

D. Ocular foreign body. Ultrasound can be a rapid and safe method to evaluate ocular foreign bodies, provided there is no evidence of globe rupture. When conducting an exam for foreign bodies, be sure to fan the transducer throughout the globe in multiple planes to assess the entire structure as foreign bodies can be present in any portion, including the anterior chamber. Foreign bodies may vary in their appearance depending on the material but typically have a hyperechoic appearance with reverberation artifact if metallic in nature. In addition to evaluating for the foreign body itself, it is importance to evaluate for signs of injury such as vitreous hemorrhage or lens dislocation. Ultrasound evaluation of intraocular foreign bodies has a high sensitivity and specificity (80%–90%) even for novice sonographers (Sargsyan et al. 2008). Combined with a plain film X-ray to detect metallic foreign bodies, POCUS has a sensitivity and specificity similar to CT (Nie et al. 2012).

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Yeh S, Colyer MH, Weichel ED. Current trends in the management of intraocular foreign bodies. *Curr Opin Ophthalmol*. 2008;19(3):225–233.

Keywords/Tags: Intraocular foreign body, ocular trauma

21. EXPLANATION

B. Magnetic resonance imaging (MRI). Though POCUS is a useful skill in assessing for ocular foreign bodies, it cannot completely rule out the presence of an ocular foreign body. The patient does have a corneal abrasion, but the presence of a positive Seidel's suggests penetration of the anterior chamber of the eye. Thus ocular foreign body is highly likely and the patient cannot be discharged home as proposed by choice C. X-rays can be useful for metallic foreign bodies, but studies have shown that it poorly detects small organic materials. CT is the study of choice for metallic foreign bodies but performs poorly for wooden foreign bodies. MRI is the test of choice for organic materials such as wooden foreign bodies (Javadrashid et al. 2017).

Learning Points: When intraocular foreign body is highly suspected and POCUS is negative, order more advanced imaging such as CT scan for metallic foreign body and MRI for organic foreign body.

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Keywords/Tags: Intraocular foreign body, ocular trauma

22. EXPLANATION

D. All of the above. The depicted image is a suboptimal ocular ultrasound study for all of the reasons listed. First, you will notice based on the curved footprint at the top of the image that the curvilinear transducer is used. While the curvilinear transducer is useful in evaluating deeper structures typically in the abdomen, the linear transducer is best for evaluating superficial structures due to its higher frequency and corresponding greater resolution. The linear transducer has a flat footprint. Next, you will see that the depth extends to 15 cm, which is not necessary when evaluating a superficial structure such as the eye. Decreasing depth allows you to focus on and gives you the greatest resolution for the area of interest. Typically, no more than a depth of 5 cm is sufficient. The image is also on the incorrect preset of abdomen rather than ocular or small parts, which would be available with the linear probe. Other methods not listed that can improve an ocular study include using copious gel and adjusting gain.

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Keywords/Tags: Image optimization, best practice, knobology

23. EXPLANATION

C. Retrobulbar hematoma. The ultrasound image is that of a retrobulbar hematoma causing deformation of the posterior globe from a spherical shape to a conical shape. This is referred to as the "guitar pick sign" (Figure 12.24c). Although retrobulbar hematoma following blunt ocular trauma is rare, it is more likely in this coagulopathic patient. It most commonly occurs due to nondisplaced orbital wall fractures causing bleeding into the retroorbital space. The blood then exerts mass effect on nearby orbital structures, which are responsible for typical findings such as eye pain, exophthalmos, ophthalmoplegia, proptosis, and pupillary dysfunction. Recognition of this diagnosis is critical as it carries serious vision-threatening consequences and may necessitate emergent lateral canthotomy. Choice A is incorrect as there is no evidence of intraocular globe rupture. Choice B is incorrect since no evidence of foreign body is seen inside the vitreous chamber. Choice D is incorrect since the optic nerve is not assessed in this view to measure ICP.

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Keywords/Tags: Retrobulbar hematoma, ocular trauma, guitar pick sign

24. EXPLANATION

C. "Though there is a small theoretical risk of thermal injury, this exam is rapidly conducted, minimizing the risk." As with all procedures, ocular ultrasound examinations require informed consent with patients. Prior to beginning an examination, the conversation between the clinician and patient affords opportunities to elucidate confusion, apprehension, goals, and limitations of the study.

The risk associated with ultrasound is that of thermal injury to tissues adjacent to the ultrasound beam. The greatest temperature increases are associated with bone due to its ready absorption of ultrasound. The eye, however, is of particularly higher risk due to its relatively low perfusion and consequently reduced ability to dissipate heat, especially the lens. Despite this theoretical risk, POCUS studies are generally not long enough (<5 min) to warrant any significant concern. To maintain this low risk, all ocular ultrasound should be performed with the ALARA principle in mind.

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Keywords/Tags: Informed consent, safety, ALARA

25. EXPLANATION

C. Ocular-digital massage, emergent ophthalmology consult with possible hyperbaric chamber treatment. Central retinal artery is a branch of the ophthalmic artery that supplies blood mainly to the retina via retinal branches, therefore an occlusion of the retinal artery may lead to an ocular stroke. Patients with CRAO may present with painless and sudden vision loss on one eye. A funduscopic exam would reveal a pale retina due to retinal edema, secondary to the occlusion, with the characteristic cherry-red spot at the fovea and attenuation of the retinal arteries. Risk factors include elderly patients older than 70, atherosclerosis, diabetes, hypertension, high cholesterol levels, carotid artery stenosis, and hypercoagulable states. Symptoms and signs of CRAO must be considered an ocular emergency and necessitate an ophthalmology consult because irreversible damage occurs in as little as 100 minutes of occlusion.

Bedside ocular ultrasound typically looks for alternative pathologies of painless vision loss such as retinal hemorrhage or vitreous hemorrhage. However, the presence of hyperechoic material in retrobulbar region may suggest embolus in the retinal artery (Figure 12.17). Additionally, orbital color Doppler imaging has been used to indirectly diagnose an embolism in CRAO when emboli cannot be directly visualized in the retinal circulation. Recognition of emboli has important management implications for these patients. Management options include ocular-digital massage to help dislodge the embolus further into the distal branch to minimize retinal ischemia or lower intraocular pressure with IV mannitol or oral/IV acetazolamide (Diamox). The last resort of treatment is hyperbaric chamber; therefore, the correct answer is C. In addition, in acute presentations of CRAO, neurology consultation should be considered for evaluation of the etiology and discussion of treatment (e.g., fibrinolysis), as CRAO is the ocular equivalent (and central nervous system extension) of a cerebrovascular event.

Laser photocoagulation is the treatment of choice for various retinal diseases such as RD and some cases of CRVO, so choice A is incorrect. Choice B is incorrect because it is the medical treatment option for CRVO. Choice D is incorrect since iridotomy treats acute glaucoma.

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Keywords/Tags: Central retinal artery occlusion, ocular embolus

26. EXPLANATION

A. Artificial lens. An artificial lens implant, or pseudophakia, is shown in the ultrasound image. Artificial lenses, and other ocular foreign bodies, often exhibit a series of horizontal lines echoing downwards beneath them, known as reverberation artifact. This occurs due to the bouncing of the ultrasound pulse between 2 parallel surfaces, in this case the borders of the artificial lens. The patient in question likely had a lens implant 1 month prior to replace a lens with advanced cataract (described in the left eye) and currently an incidental conjunctivitis. Choice B is incorrect as the lens is appropriately located symmetrically in the anterior portion of the posterior chamber. Choice C is incorrect because, while the patient does likely have cataracts, that is not visualized on the ultrasound. Cataracts would have the appearance of an echogenic thickened lens on ultrasound replacing the normally curved linear appearance. Choice D is incorrect as vitreous hemorrhage has an appearance of clothes in a washer (washing machine sign). The patient's clinical presentation is also not consistent with vitreous hemorrhage.

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Keywords/Tags: Artificial lens, artifacts, lens, cataract

27. EXPLANATION

A. Exudative retinal detachment. The patient's fundoscopic exam reveals a melanoma with associated RD, which

is demonstrated on the ultrasound. RDs are traditionally classified into 3 types with decreasing prevalence respectively: rhegmatogenous, tractional, and exudative. In exudative, there is a disturbance in the blood retinal barrier causing fluid to accumulate in the subretinal space. Though uncommon, the conditions associated with exudative RDs are numerous, including iatrogenic, infectious, malignant, or genetic. Both rhegmatogenous and tractional RD are associated with accumulation of vitreous fluid in the sub retinal space due to a discontinuity in the retina or physical forces lifting the retina off the choroid, respectively. These 2 more common causes of RD result in a ribbon like appearance of the retina. In contrast, exudative RD has a flattened appearance with echogenic fluid underneath. Therefore, choice C is incorrect. Choices B and C are incorrect: CRVO and CRAO typically require Doppler to assess for vascular flow deficits or ultrasound is used to visualize emboli in the retrobulbar space.

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Keywords/Tags: Exudative retinal detachment

13.

PROCEDURAL ULTRASOUND

Poornima Yechoor, Emily Lovallo, Andrea Dreyfuss, and Arun Nagdev

QUESTIONS

1. A 52-year-old female with end-stage liver disease presents with a painful and distended abdomen. How should you use ultrasound to perform a bedside paracentesis?

A. Identify the largest pocket of fluid for aspiration
B. Identify the inferior epigastric arteries
C. Avoid the bladder
D. All of the above

2. A 67-year-old male with chronic obstructive pulmonary disease on 4L oxygen, hypertension, and congestive heart failure presents with a right shoulder dislocation. The patient is a known CO2 retainer and often desaturates with any reduction of ventilatory effort. To avoid procedural sedation, ultrasound guidance is chosen to facilitate a closed reduction. Which technique could safely be used in this patient?

A. Interscalene brachial plexus block
B. Supraclavicular brachial plexus block
C. Intra-articular shoulder injection
D. Infraclavicular brachial plexus block

3. A 75-year-old male presents with a warm, swollen left knee with decreased range of motion. There is no trauma history. You are concerned about a septic joint and use ultrasound to evaluate for an effusion in the suprapatellar space (yellow triangle in Figure 13.1). Which structure is visualized (red arrows) on ultrasound and should be avoided during knee aspiration?

A. Quadriceps tendon
B. Patellar tendon
C. Iliotibial band
D. Vastus lateralis

**4. An 85-year-old female presents in septic shock from pneumonia. She has difficult peripheral intravenous (IV) access and is requiring escalating doses of vasopressors for blood pressure support. During your survey ultrasound of her central veins, you find both her left

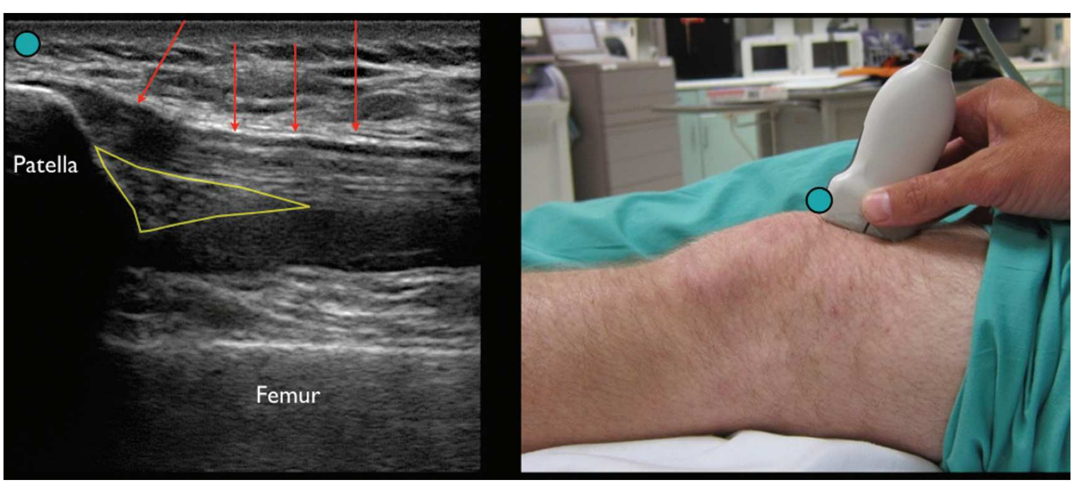

Figure 13.1

and right internal jugular veins (IJVs) lie directly above the carotid arteries and collapse completely with inspiration. Which approach to IJV cannulation has been shown to allow better visualization of needle placement and may reduce posterior wall punctures?

A. Longitudinal long-axis approach
B. Short-axis approach
C. Oblique approach
D. Landmark-based approach

5. A 27-year-old female presents with a large deltoid abscess from intramuscular injections of heroin. You plan for an ultrasound-guided interscalene nerve block instead of procedural sedation. You obtain the ultrasound seen in Figure 13.2. Which structure is vasculature?

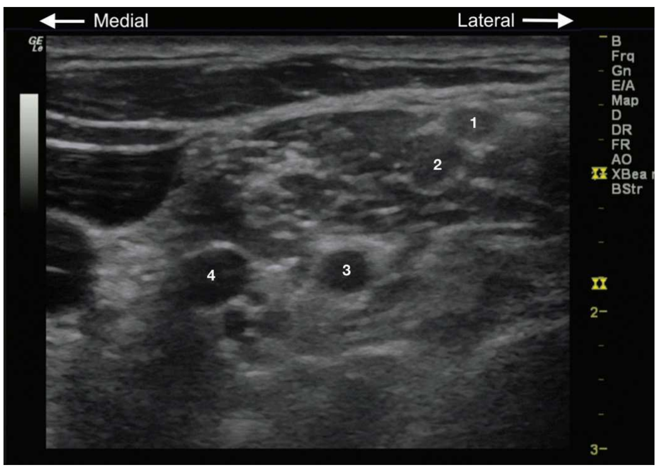

Figure 13.2

A. 1
B. 2
C. 1+2
D. 4

6. A 17-year-old female presents with a posteriorly dislocated left elbow sustained during a hockey match. She is neurovascularly intact on exam. Which of the following is *not* a reliable option for analgesia to reduce her elbow?

A. Brachial plexus nerve block at the interscalene level
B. Brachial plexus nerve block at the supraclavicular level
C. Intra-articular anesthetic injection
D. Brachial plexus nerve block at the infraclavicular level

7. A 27-year-old obese female presents with headache and peripheral vision loss. You would like to assess her central spinal fluid opening pressure with a lumbar puncture but are finding a landmark-based approach challenging. Which of the following structures will you use to mark the inter-spinous spaces (see Figure 13.3)?

Figure 13.3

A. 1
B. 2
C. 3
D. 4

8. A 65-year-old male is brought to the ED by paramedics after being hit by a car as he walked across a street. He has multiple bony and soft tissue injuries to the lower extremities. Pain from which of the following injuries will *not* be alleviated with a femoral nerve block?

A. Tibia-fibula fracture
B. Femur fracture
C. Deep abrasion to the lateral thigh
D. Deep abrasion to the medial lower leg

9. A 78-year-old male is brought in from a skilled nursing facility in cardiac arrest. His pulse oxygen monitor has a good waveform with values around 88%–92%, with bag valve mask ventilation and chest compressions. However, there is difficulty with peripheral IV access, and the intraosseous access device is not available. To minimize interruptions in chest compressions, you decide to perform a supraclavicular approach to subclavian vein cannulation. You get good visualization of the subclavian vein (see Figure 13.4). What probe are you using, and where is it positioned?

A. Linear probe, infraclavicular
B. Linear probe, supraclavicular
C. Endocavitary probe, supraclavicular
D. Endocavitary probe, infraclavicular

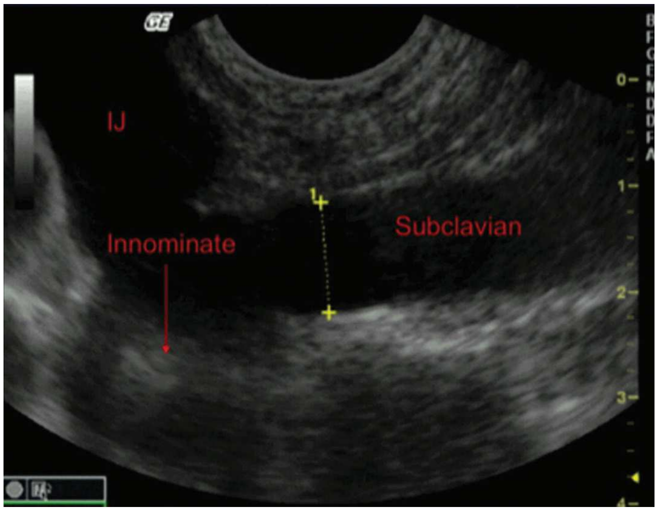

Figure 13.4 **Ultrasound visualization of subclavian and innominate veins.** IJ = internal jugular vein. Adapted from Figure 1 of Mallin M, Louis H, Madsen T. A novel technique for ultrasound-guided supraclavicular subclavian cannulation. *Am J Emerg Med.* 2010;28(8):966–969. doi:10.1016/j.ajem.2009.07.019.

10. An elderly female with multiple medical problems presents with a proximal femur fracture after a fall. You decide regional anesthesia is the best option for her for pain control given her comorbidities. Which number corresponds the target site for local anesthetic delivery in a fascia iliaca compartment block on the ultrasound image shown in Figure 13.5?

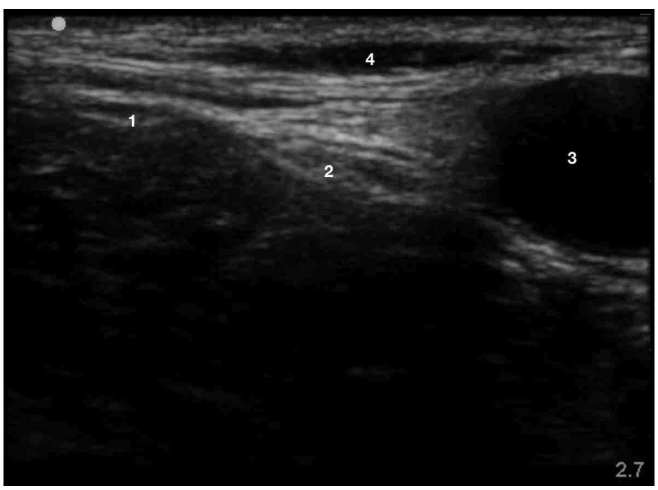

Figure 13.5

A. 1
B. 2
C. 3
D. 4

11. Where should the ultrasound system *not* be placed to perform a right-sided femoral nerve block using a long-axis approach (Figure 13.6)?

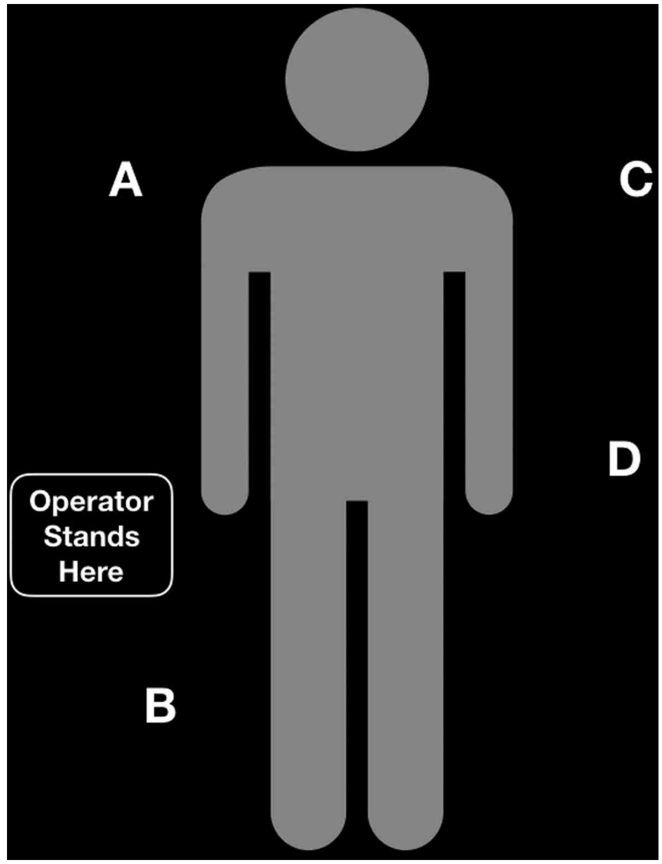

Figure 13.6

A. A
B. B
C. C
D. D

12. At which site would it be ineffective to use regional anesthesia for pain control to reduce a displaced distal radius fracture?

A. Supraclavicular brachial plexus block
B. Infraclavicular brachial plexus block
C. Axillary brachial plexus block
D. Radial nerve forearm block

13. A 39-year-old female pedestrian is brought in by ambulance after being hit by a motor vehicle at high speed. She was found to have faint pulses in the field but has lost pulses during her initial evaluation in the ED. She is currently in a c-collar with cardiopulmonary resuscitation (CPR) in progress. IV access was unobtainable by emergency medical services and on initial attempt in the ED. Which site should you choose to obtain rapid IV access to continue the resuscitation?

A. Keep trying for a peripheral IV
B. Internal jugular vein

C. Subclavian vein
D. Femoral vein

14. A 64-year-old male presents with shortness of breath and hypotension to 70/40. A chest X-ray shows clear lungs and an enlarged cardiac silhouette, and your bedside cardiac ultrasound confirms the presence of a large circumferential pericardial effusion with echocardiographic signs of tamponade. Which probe and technique do you choose to perform a pericardiocentesis with dynamic needle visualization?

A. Linear probe, in-plane
B. Phased array probe, out of plane
C. Curvilinear probe, in-plane
D. Endocavitary probe, out of plane

15. A 47-year-old female with end-stage renal disease on dialysis presented with acute cardiac tamponade, and you have successfully aspirated 500 mL of serous fluid with an ultrasound-guided pericardiocentesis. In addition to the patient's symptomatic improvement, what are 2 sonographic signs that you have adequately drained the pericardial effusion?

A. Decreased size or resolution of the pericardial effusion and increase in IVC variability
B. Decreased size or resolution of the pericardial effusion and decrease in IVC variability
C. Increase in right ventricle free wall collapse and increase in IVC variability
D. Decrease in cardiac chamber size and decrease in IVC variability

16. An 82-year-old female is brought in with a pulseless electrical activity (PEA) arrest and CPR is in progress. She regains pulses, and on your bedside cardiac ultrasound you identify a large pericardial effusion with sonographic signs of tamponade. You consider both parasternal and subxiphoid approaches to ultrasound-guided pericardiocentesis. What are 2 disadvantages to performing a pericardiocentesis using a subxiphoid approach?

A. Higher risk of pneumothorax and higher risk of lacerating the internal mammary arteries
B. Inability to visualize the needle in plane and necessity of traversing the liver
C. Higher risk of coronary artery or myocardial injury
D. All of the above

17. A 49-year-old male with a history of metastatic lung cancer presents with worsening shortness of breath and orthopnea. He has diminished breath sounds throughout on exam and a chest X-ray done as part of his initial workup shows a large pleural effusion in his right chest. You decide to perform an ultrasound-guided thoracentesis. What probe should you use, and how do you optimally position the patient for the procedure?

A. Phased array probe, patient sitting up
B. Linear probe, patient supine
C. Curvilinear probe, patient supine
D. None of the above

18. Which letter corresponds to the diaphragm on the image in Figure 13.7?

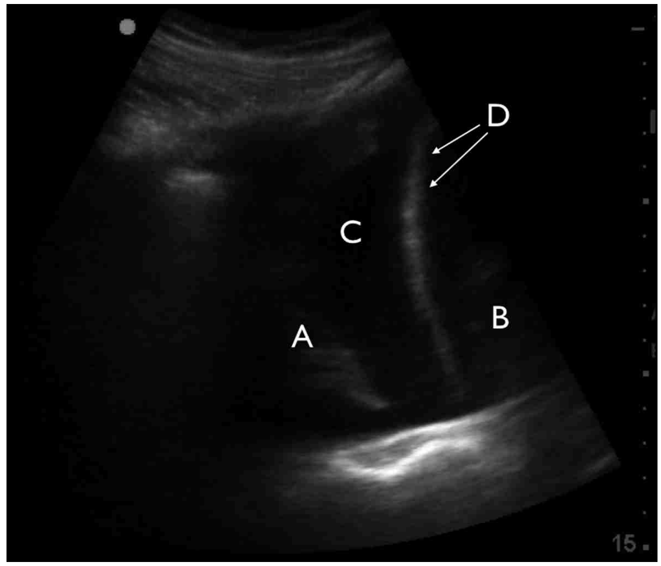

Figure 13.7

A. A
B. B
C. C
D. D

19. A 29-year-old male with a history of HIV presents with fever, cough, and shortness of breath. He is ill appearing, tachypneic, and hypoxic on your evaluation. Chest X-ray reveals a large left-sided pleural effusion. You perform a bedside ultrasound to evaluate the effusion for possible thoracentesis. What features on your ultrasound would alert you that a bedside thoracentesis may not be successful and that thoracic surgical intervention may be needed?

A. Plankton or hematocrit sign
B. Presence of loculations and septations
C. Homogenous anechoic character
D. All of the above

20. A 22-year-old female falls onto her left arm while playing soccer and presents with severe pain in the forearm. On physical examination, she has swelling and slight deformity over the site with a good radial pulse. A plain

film confirms the presence of a both bone mid-forearm fracture with minimal displacement and comminution. Which of the following ultrasound-guided nerve blocks will provide effective analgesia for her injury?

A. Ulnar nerve block at the forearm
B. Radial nerve block at the forearm
C. All of the above
D. None of the above

21. A 31-year-old male presents with left hand pain after a fistfight. His whole hand is swollen and bruised, and he is diffusely tender. An X-ray shows a transverse fracture through the neck of the fifth metacarpal bone. Which of the following ultrasound-guided forearm nerve blocks will provide the most effective anesthesia for this particular injury?

A. Radial nerve block
B. Ulnar nerve block
C. Median nerve block
D. Axillary nerve block

22. A 37-year-old female who works as a chef presents after a knife injury. She has normal vitals, and on physical exam you observe a 6 cm vertical laceration of her left hand that extends from the base of the palm up to nearly the tip of her middle finger. She is neurovascularly intact and in a significant amount of pain. Before exploring the wound and repairing the laceration, you decide to perform a forearm nerve block for anesthesia and analgesia. Which nerve should you block, and where can you identify it using ultrasound?

A. Radial nerve adjacent to the radial artery in the distal forearm
B. Median nerve between the flexor digitorum superficialis and the flexor digitorum profundus at the mid-forearm
C. Ulnar nerve adjacent to the ulnar artery in the distal forearm
D. A distal median nerve block at the carpal tunnel

23. A 49-year-old male was seen in the ED 2 days ago after he suffered a cat bite to his right hand. He was discharged home with antibiotics after the wound was irrigated and a tetanus booster was given. Now he presents with worsening pain, swelling, and redness over the region and noted purulent drainage this morning. On examination, you note a 3 × 3 cm abscess at the base of the dorsal aspect of his right hand near the thumb. You decide to perform an ultrasound-guided radial nerve block before draining the abscess. Which probe and orientation do you use to perform this block?

A. Linear probe, transverse orientation
B. Curvilinear probe, longitudinal orientation
C. Phased array probe, longitudinal orientation
D. None of the above

24. When attempting to perform a radial nerve block in preparation for a wound exploration and laceration repair over the dorsal aspect of your patient's hand, you are not able to visualize the nerve well in the forearm. Instead, you identify it much more clearly at the elbow and block the nerve there instead. Which of the following do you expect by blocking the nerve at this location?

A. Claw hand
B. Decreased duration of anesthesia
C. Weakness in extensor muscles of the hand and wrist
D. No difference compared to performing it in the forearm

25. A 27-year-old male presents after an assault during which he was punched and kicked multiple times in the chest. He is found to have multiple right-sided anterolateral rib fractures. Even after receiving nonsteriod anti-inflammatory drugs, acetaminophen, and a few doses of opiates, he is still in marked distress and is visibly splinting with respiration. Which of the following ultrasound-guided blocks will provide more effective pain control?

A. Transversus abdominis plane block
B. Serratus anterior plane block
C. Superior cervical plexus block
D. Axillary nerve block

26. You are getting ready to perform a serratus anterior plane block for a patient who is found to have multiple lateral rib fractures. You identify the ribs and serratus muscle on ultrasound. Depositing anesthetic at which of the following sites will *not* provide the desired anesthetic effect?

A. Between the serratus muscle and soft tissue anteriorly
B. Between the serratus muscle and intercostal muscles posteriorly
C. Just above the surface of the rib (between the rib and the serratus anterior muscle
D. Below the rib (between the rib and pleural line)

27. A 47-year-old male underwent an exploratory laparotomy 5 days ago after he was found to have a hemoperitoneum following a motor vehicle collision. He was prescribed hydrocodone-acetaminophen for pain control when he was discharged from the hospital. He continues to have significant postoperative pain at the surgical site in his mid-abdomen just below the umbilicus. He reports that the pain medications do not help very much and are instead making him severely

constipated. Once you have ruled out any potential postoperative complication, what is an alternate effective pain management strategy for this patient?

A. Increase the dose of his hydrocodone-acetaminophen
B. Perform an enema
C. Perform a transversus abdominis plane block
D. Perform a serratus anterior plane block

28. A 47-year-old male presents with acute renal failure and a potassium level of 7.3. You are placing a quinton catheter in the patient's IJV so that he can be emergently dialyzed when he suddenly starts to complain of sharp chest pain and shortness of breath. On the monitor, you note that he starts to desaturate to 87% on room air. Which of the following is the most appropriate next step after you have placed the patient on oxygen?

A. Continue placing the quinton catheter so that dialysis can be initiated.
B. Order a computer tomography (CT) of the chest to evaluate for pulmonary embolism.
C. Stop the procedure and ultrasound the chest to look for a pneumothorax.
D. Order an electrocardiogram (EKG) and an aspirin.

29. A 25-year-old male presents to the ED after a laceration to the sole of his foot. What block would be ideal for analgesia for this injury?

A. Sural nerve block
B. Femoral nerve block
C. Posterior tibial nerve block
D. Lateral femoral cutaneous block

30. A 28-year-old male presents with deformity of his right lower ankle and wounds mainly on the lateral side of the leg after he stepped into a hole while running. You decide to do a nerve block after you see that he has a bimalleolar ankle fracture on X-ray.
The sciatic nerve block will *not* provide any analgesia to which of the following injuries?

A. Bimalleolar ankle fracture
B. Achilles tendon rupture
C. Large lateral leg laceration
D. Laceration to medial lower leg

31. You are attempting to perform a sciatic nerve block for a patient with an ankle fracture and see the image in Figure 13.8. What techniques can be performed to improve distal sciatic nerve visualization?

A. Tilting the probe to become perpendicular to the nerve
B. Finding the popliteal vein and artery

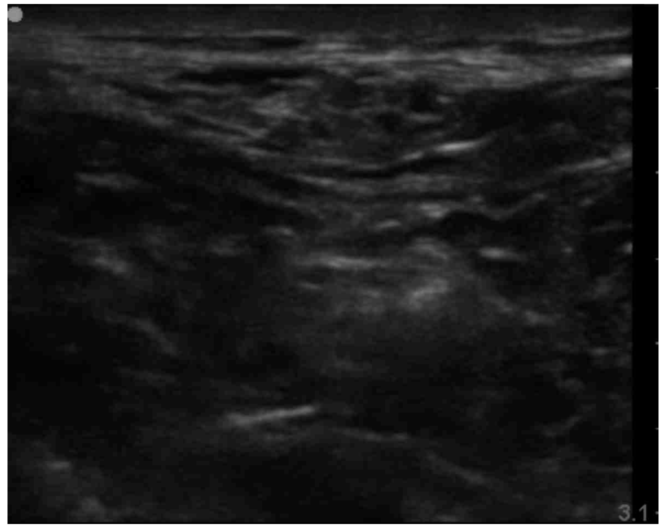

Figure 13.8

C. Asking patient to dorsiflex and plantar flex the ipsilateral foot
D. All of the above

32. You are performing an interscalene brachial plexus block when your patient becomes altered and hypotensive. What medication should you rapidly administer intravenously?

A. Bupivicaine
B. Amiodarone
C. Lidocaine
D. Intralipid

33. A 25-year-old healthy male presents to the ED after a fall onto his left side while playing basketball. You find that he has an anterior shoulder dislocation without a fracture, and attempt a reduction. You ultrasound the shoulder to assess whether you are successful (Figure 13.9). What is your next step?

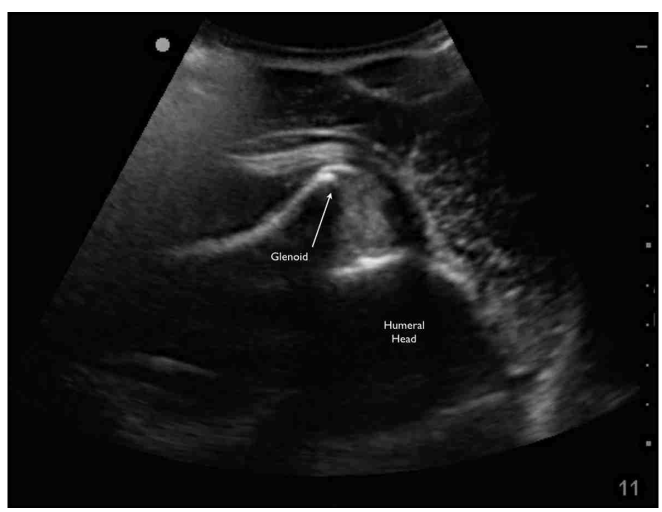

Figure 13.9

A. Place him in a sling and discharge him
B. Obtain a plain film of the shoulder
C. Reattempt your reduction
D. Consult orthopedics

34. A 34-year-old female presents to the ED after falling from a motorcycle onto her right side and is found to have a right sided angulated and dorsally displaced distal radius fracture. After successfully blocking her and attempting a reduction, you are told that there are multiple traumas that are tying up X-ray and that the tech can't get to her for at least another 30 minutes. You ultrasound her wrist and see the following (Figure 13.10). What should you do next?

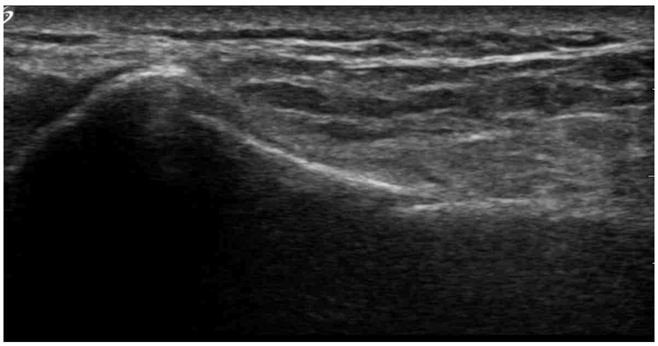

Figure 13.10

A. Emergently consult orthopedics
B. Place her in a sugar-tong forearm splint now
C. Reattempt your reduction
D. Order a CT of the wrist

35. Which of the following letters corresponds to the cricothyroid membrane (Figure 13.11)?

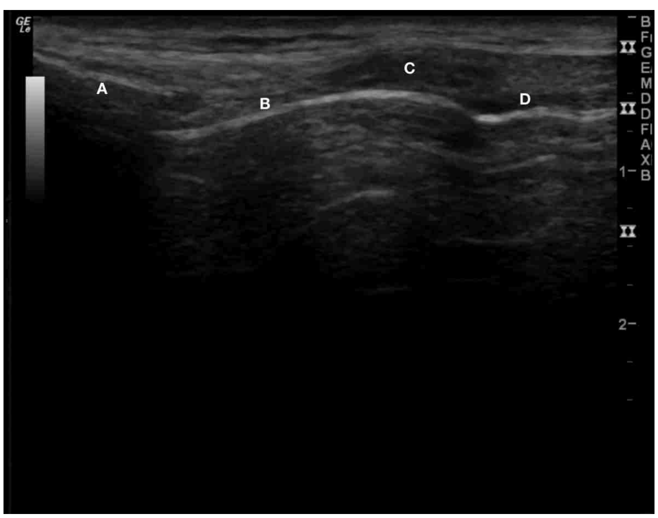

Figure 13.11

A. A
B. B
C. C
D. D

36. A 54-year-old male who is in recovery from heroin addiction presents after being involved in a motor vehicle collision. He is found to have severe pulmonary contusions bilaterally as well as a severely comminuted left proximal humerus fracture. He is currently on 6L of O2 via a facemask. After acetaminophen and ketorolac, he still reports severe pain in his arm. He insists he does not want any opiates. Which of the following would be most appropriate for better pain control?

A. Ultrasound guided interscalene brachial plexus block
B. Try to convince him to take a dose of morphine
C. Ultrasound guided serratus anterior plane block
D. Ultrasound guided hematoma block

37. A 39-year-old female with history of active intravenous drug use presents with a fever and inability to bear weight on her right lower extremity. On your exam, she has exquisite pain on both active and passive range of motion of her right hip, and your ultrasound demonstrates a moderate right hip effusion. You are concerned she may have a septic hip. Which transducer/approach would you use to perform an ultrasound-guided hip arthrocentesis?

A. Phased array, out of plane
B. Curvilinear, in-plane
C. Linear, out of plane
D. Curvilinear, out of plane

38. A 64-year-old diabetic male with a long-standing history of gout presents with a warm, red, swollen left ankle that has been worsening over the last 3 days. He is having a great deal of difficulty ambulating due to pain. He reports no trauma, and he says he usually experiences knee or great toe swelling when his gout flares. On your exam, he has a low-grade fever to 100.8, appears very uncomfortable, and has severe pain with any range of motion of his left ankle. Which of the following is the most appropriate next step?

A. Place a linear probe at the junction of the tibia and talus and perform an arthrocentesis using an out of plane approach
B. Place a linear probe over the lateral malleolus and perform an arthrocentesis using an in-plane approach
C. Place a phased array probe at the medial malleolus and perform an arthrocentesis
D. It is likely a gout flare—no imaging is needed. Treat him with NSAIDs, consider colchicine and have him see his PMD

39. A 21-year-old male with history of sickle cell anemia with priapism. He has already been given acetaminophen, NSAIDs, and several doses of IV hydromorphone with minimal relief of his pain. As you prepare for aspiration and intra-cavernous phenylephrine injection, you decide to perform an ultrasound-guided dorsal penile nerve block. Which of the following corresponds to your target site for injecting local anesthetic?

A. Above Buck's fascia
B. Below Buck's fascia
C. Corpus cavernosum
D. Urethra

40. A 47-year-old morbidly obese female with history of severe Raynaud's presents in cardiac arrest. After a few rounds of ACLS, you feel a faint femoral pulse, but you are unable to get a reliable manual blood pressure. You decide to place an arterial line. With her Raynaud's and severe hypotension, she has radial and brachial arteries that are barely visible poor targets, so you decide to put in a femoral arterial catheter. Which of the following corresponds to the femoral artery in Figure 13.12?

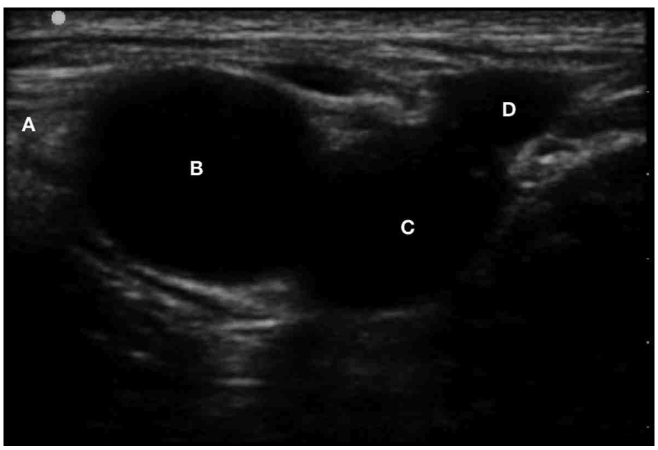

Figure 13.12

A. A
B. B
C. C
D. D

41. A 59-year-old male presents with severe back and leg pain with blood pressures in the 230s/120s. On your evaluation, you find that he has a large aortic dissection extending from his aortic root down to his iliac vessels. As you start him on an esmolol drip while he awaits thoracic surgical evaluation, you also decide to place a radial arterial line to help you monitor his blood pressures accurately and to effectively titrate his medications. Which of the following describes the appropriate transducer/approach to use for ultrasound-guided radial arterial catheterization?

A. Linear probe, out of plane
B. Phased array probe, out of plane
C. Linear probe, in-plane
D. A and C

42. A 47-year-old female underwent a cardiac catheterization for a myocardial infarction 1 week ago. She had 2 stents placed in her coronary vessels and was doing well until 2 days ago when she noted worsening swelling and pain over the access site in her right groin, and she is worried she now has an infection. On exam, she is well appearing but has a 3 × 3 cm area of warmth and induration over the right groin with mild overlying erythema. You place an ultrasound over the affected area and see the images in Figure 13.13 and Video 13.1. What is the best next step?

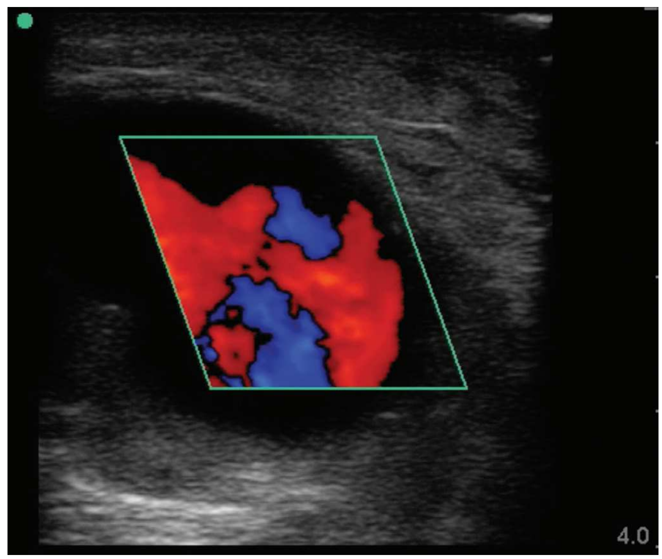

Figure 13.13

A. Perform an I&D to drain the abscess.
B. Start her on antibiotics.
C. Order a CT angiogram and consult vascular surgery.
D. Reassure her and discharge her home.

43. An 81-year-old female presents to the ED after a syncopal episode and is noted to be severely and persistently bradycardic and hypotensive. You do an EKG and find her to be in complete heart block. After unsuccessfully trying to pace her transcutaneously, you decide to insert a transvenous ventricular pacemaker before you send her to the intensive care unit where she will await

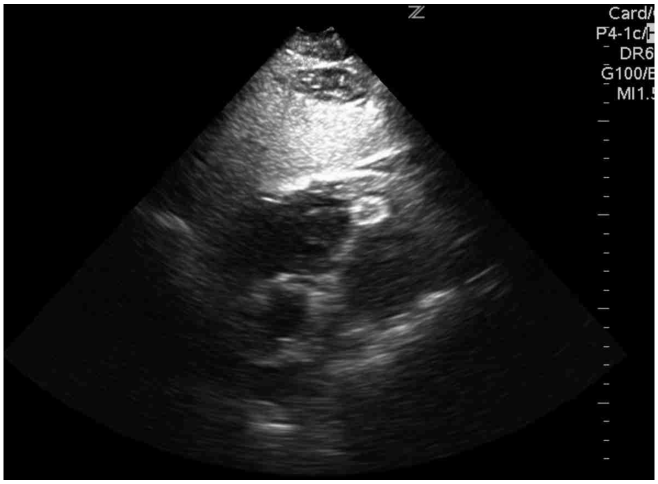

Figure 13.14

placement of a permanent pacemaker in the morning. Once you place the lead, you obtain a point of care echo that shows the images in Figure 13.14 and Video 13.2. What should you do next?

A. Continue to advance the catheter.
B. Pull back the catheter.
C. Turn on the color Doppler setting.
D. Begin pacing the patient.

ANSWERS

1. EXPLANATION

D. All of the above. Ultrasound-guided paracentesis has been shown to be more effective at removing ascites and has fewer complications than the traditional landmark-based approach. Although iatrogenic injury to the inferior epigastric artery is uncommon, it is potentially life-threatening, and can lead to hemorrhage or pseudoaneurysm formation—if possible, the artery should be localized sonographically prior to puncture (Figure 13.15, Video 13.3). Ultrasound can also ensure that the bladder is adequately distended and not in the projected path of the needle. Most importantly, ultrasound can confirm that there is adequate ascites to safely aspirate and should be used prior to the procedure to identify the required depth and trajectory of needle, regardless of the estimated ascitic volume.

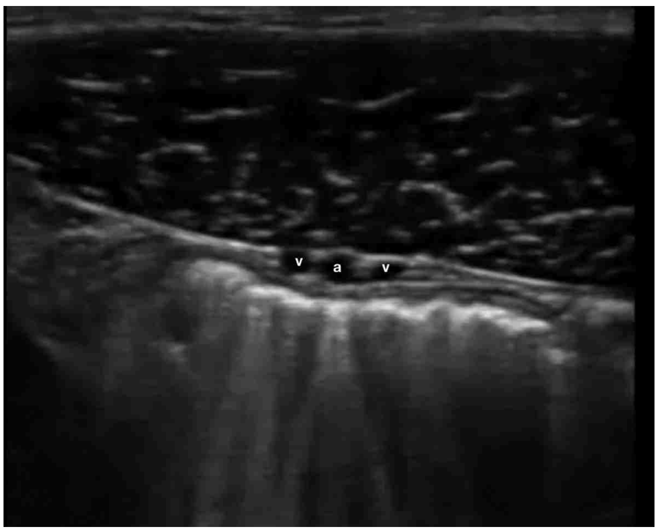

Figure 13.15 **Inferior epigastric artery (a) seen above the parietal peritoneum.** v = inferior epigastric vein.

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Keywords/Tags: Paracentesis, acquisition

Learning Point 1: When performing a paracentesis, ultrasound should be used to identify both the inferior epigastric arteries and an adequate pocket of fluid to aspirate

2. EXPLANATION

C. Intra-articular shoulder injection. An ultrasound-guided brachial plexus block at the interscalene level would provide anesthesia to the shoulder but often causes hemi-diaphragmatic paralysis due to ipsilateral phrenic nerve blockade. Smaller volumes (<10 mL) may decrease the risk of hemi-diaphragm paralysis, but the risk could be highly problematic in a patient with fragile respiratory status such as the one in this case. An intra-articular shoulder injection is a good option and can be approached through out-of-plane or in-plane technique (Figure 13.16a). An in-plane technique is preferred, as minimal needle adjustment is required, which can be confusing given the orientation of needle and probe when approaching the shoulder joint (Figure 13.16b, Video 13.4). Ultrasound-guided approach

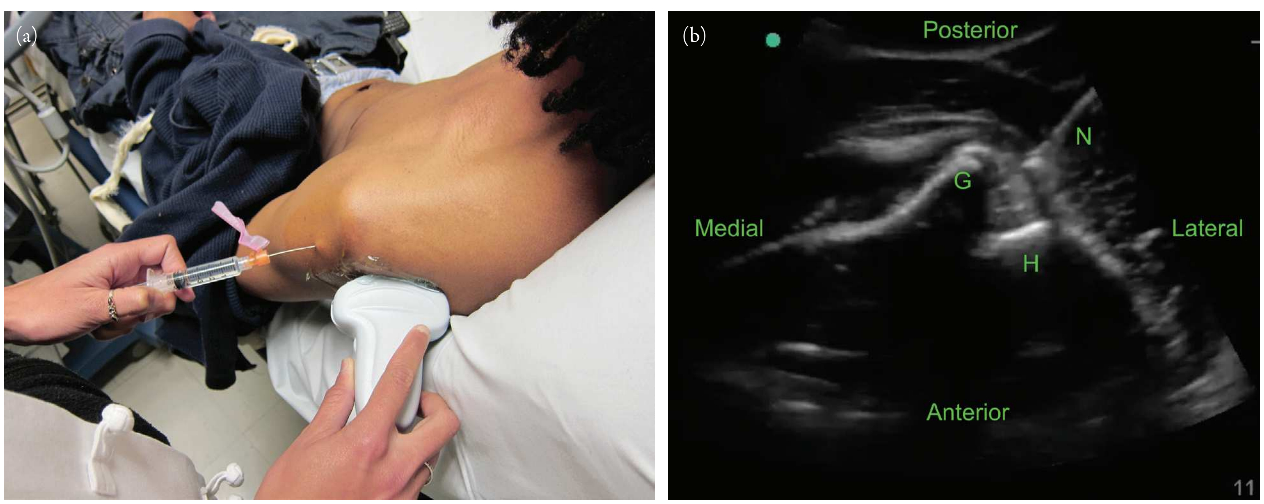

Figure 13.16 (a) **In-plane shoulder injection patient positioning.** (b) **In-plane shoulder injection.** The ultrasound probe is placed on the posterior shoulder, pointed anteriorly. The needle (N) is visualized in an in-plane approach, directed towards the intra-articular space between the glenoid rim (G) and the anteriorly displaced humeral head (H).

to the shoulder joint has been shown to increase accuracy of joint injection. When compared to procedural sedation for shoulder relocation, intra-articular injection use also decreases emergency department (ED) length of stay and complication rate.

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Keywords/Tags: Shoulder dislocation, shoulder injection

Learning Point 2 (advanced): Intra-articular ultrasound-guided glenohumeral injection can be used for shoulder dislocations

3. EXPLANATION

A. Quadriceps tendon. The image shows the suprapatellar anatomy using the linear probe placed at midline of the knee, with the indicator facing toward the patient's feet. The indicated structure (red arrows) is the quadriceps tendon (Figure 13.1). By moving the probe slightly lateral to midline, the tendon can be avoided during the arthrocentesis. Knee arthrocentesis under ultrasound guidance has been shown to require fewer attempts and to decrease patient discomfort when compared to landmark-based techniques.

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Keywords/Tags: Knee arthrocentesis, acquisition, anatomy

Learning Point 3: Ultrasound guidance for knee arthrocentesis has been demonstrated to require fewer attempts and less patient discomfort, as compared to a landmark-based technique. Ultrasound should be used to avoid penetrating the quadriceps tendon.

4. EXPLANATION

C. Oblique approach. Ultrasound guidance has been demonstrated to reduce complications and improve success rates compared to the landmark-guided technique during central venous catheterization and is recommended by the Agency for Healthcare Research and Quality. Yet arterial injury and cannulation with subsequent complications still occur. Studies show fewer posterior-wall puncture injuries, larger transverse diameter of the IJV, and less overlap between the carotid artery and IJV with a medial-oblique probe position (Figure 13.17). To obtain this view, the probe is first placed in traditional short-axis view between the sternocleidomastoid heads, then rotated approximately 30° counterclockwise, in a medial-inferior to lateral-superior direction. This view allows for direct continuous visualization of the needle while maintaining excellent targets for cannulation – an optimal combination of the transverse and longitudinal approaches.

Figure 13.17 **Needle entering internal jugular vein on oblique view.**

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Keywords/Tags: Central venous access

Learning Point 4 (advanced): When placing a central venous catheter in the internal jugular vein (IJV), confirmation of wire placement should be performed in longitudinal view prior to dilation. There may be an advantage in visualization with an oblique view.

5. EXPLANATION

D. 4. The roots, trunks, and cords of the brachial plexus appear as homogeneous, hypoechoic structures, tubular in longitudinal views and oval in axial views, quite similar to the sonographic appearance of vascular structures (Figure 13.18a). The vessels adjacent to the brachial plexus are the vertebral artery and veins. Below the level of the clavicle the brachial plexus takes on an appearance typical to that of other peripheral nerves, hypoechoic bundles embedded in hyperechoic supporting connective tissue and surrounded by the hyperechoic epineurium. For this reason, in the neck especially, care must be taken to distinguish the nerves from vessels. Color Doppler is a useful modality to differentiate vascular structures from nerve bundles (Figure 13.18b)

A linear transducer is placed at the level of the cricoid cartilage in a posterior-lateral to anterior-medial plane, just lateral to the IJV and carotid. The head should be rotated contralaterally to displace the sternocleidomastoid muscle more medially. The needle is inserted in a posterior-lateral to anterior-medial position into the fascia between the anterior and middle scalene muscle, and anesthetic should be injected using hydro-dissection (Figure 13.18c).

A brachial plexus block at the interscalene level will anesthetize the majority of the shoulder and upper arm to approximately the mid-humerus level. Disadvantages to the interscalene brachial plexus block include hemi-diaphragm paralysis from phrenic nerve blockade, ipsilateral Horner's syndrome, nerve injury, as well as intravascular injection of local anesthetic.

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Keywords/Tags: Brachial plexus, regional anesthesia

Learning Point 5 (advanced): Color flow evaluation of brachial plexus structures in the neck should be performed before a block. The proximal nerve roots appear anechoic above the level of the clavicle and can be difficult to differentiate from vasculature.

6. EXPLANATION

A. Brachial plexus nerve block at the interscalene level. Brachial plexus block at the interscalene level will provide anesthesia to the arm above the elbow but has inconsistent blockade of the inferior trunk (C8–T1), so it would not be an ideal choice for an elbow injury. However, a low interscalene block—about 2 to 3 cm below the level of the cricoid cartilage, has been shown to be effective for patients undergoing elbow surgery (Gadsen et al. 2009). This is midway

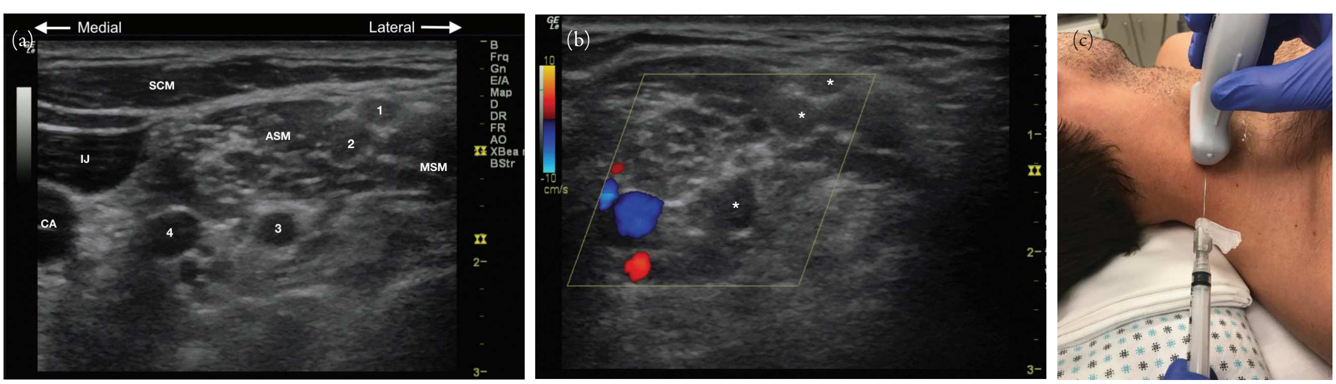

Figure 13.18 (a) **Interscalene nerve block anatomy showing brachial plexus.** 1 = C5; 2 = C6; 3 = C7; 4 = vertebral artery and veins; SCM = sternocleidomastoid muscle; IJ = internal jugular vein; CA = carotid artery. (b) **Identifying the brachial plexus using color Doppler.** Notice the brachial plexus (*) are hyper/anechoic but do not have any color flow compared to the vertebral vessels. (c) **Interscalene brachial plexus block technique.** Note that no probe cover was used to demonstrate indicator and needle alignment.

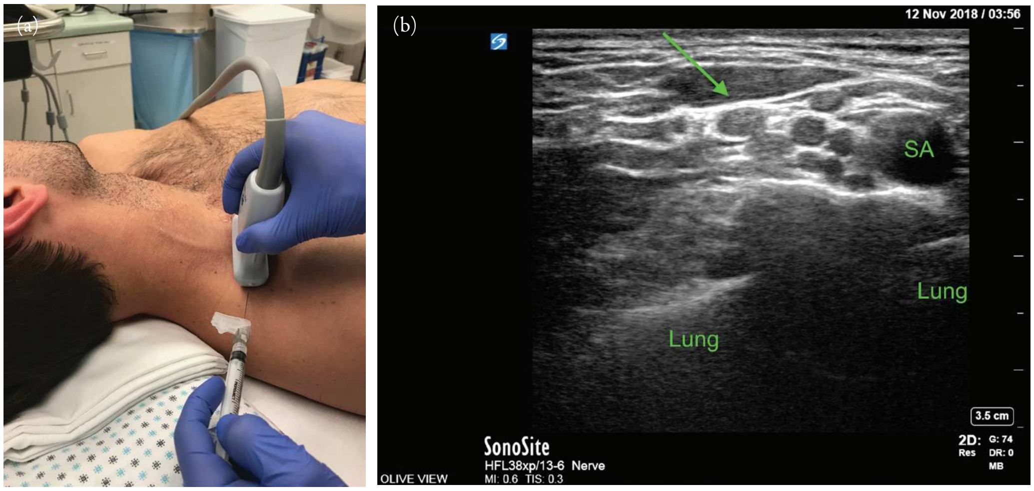

Figure 13.19 (a) **Supraclavicular brachial plexus block technique.** (b) **Supraclavicular brachial plexus block on ultrasound.** SA= subclavian artery. Arrow points to brachial plexus cords.

between an interscalene block and a supraclavicular block of the brachial plexus (Figure 13.19a). A brachial plexus block at the infraclavicular level will provide dense sensory and motor blockade to the distal upper arm including the elbow, down through the hand. There is a lower risk of phrenic nerve paralysis compared to a supraclavicular block, which will anesthetize the same regions, but it is considered more technically difficult. Compared to the interscalene block, both supraclavicular and infraclavicular brachial plexus blocks are associated with a higher risk of pneumothorax, as the pleural lining is just deep to the brachial plexus at these sites (Figure 13.19b). Although not yet described in the literature, it may be feasible to perform an intraarticular injection of local anesthetic to attempt reduction.

REFERENCES

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Nadeau M-J, Lévesque S, Dion N. Ultrasound-guided regional anesthesia for upper limb surgery. *Can J Anaesth*. 2013;60(3):304–320. doi:10.1007/s12630-012-9874-6.

Keywords/Tags: Elbow dislocation, regional anesthesia

Learning Point 6 (advanced): Brachial plexus block at the infraclavicular level will provide dense sensory and motor blockade to the distal upper arm including the elbow, down through the hand. There is a much lower risk of phrenic nerve paralysis compared to a supraclavicular block, which will anesthetize the same regions. Brachial plexus block at the interscalene level will provide anesthesia to the arm above the elbow but would not be adequate for an elbow injury.

7. EXPLANATION

C. 3. The following numbers correspond to the structures in the image: 1 = skin; 2 = muscle; 3 = intraarticular process; 4 = dura mater. Ultrasound-guided lumbar puncture has been shown to increase the success rate and decrease number of attempts and complications of the procedure.

There are several techniques described in the literature. One popular approach (Figure 13.20a) is to place the transducer in a transverse plane at or just above the iliac crest. Use M-mode to find the spinous processes between the paraspinal muscles and mark with a skin marker over at least 2 levels (top images). The connected dashes form the midline. Then rotate to a longitudinal axis along this midline to find the interspinous spaces, marking each level from L4–L5 up to L2–L3 (bottom images).

We find using the articular processes, which correspond to the interspinous spaces, to also be a reliable technique. These are found by identifying the spinous processes in midline then sliding the probe (placed longitudinally) just off the midline (paramedian) near the sacrum and identifying the rounded, hyperechoic humps of the articular processes that appear at regular intervals from the sacrum. These correspond to the L5/S1, L4/L5, and L3/L4 spaces, which should be marked on the patient's skin and used to guide needle placement (Figure 13.20b).

Note that ultrasound is not used in real-time during the procedure but to assist in locating suitable points for needle insertion, so this should be done before rendering the field sterile.

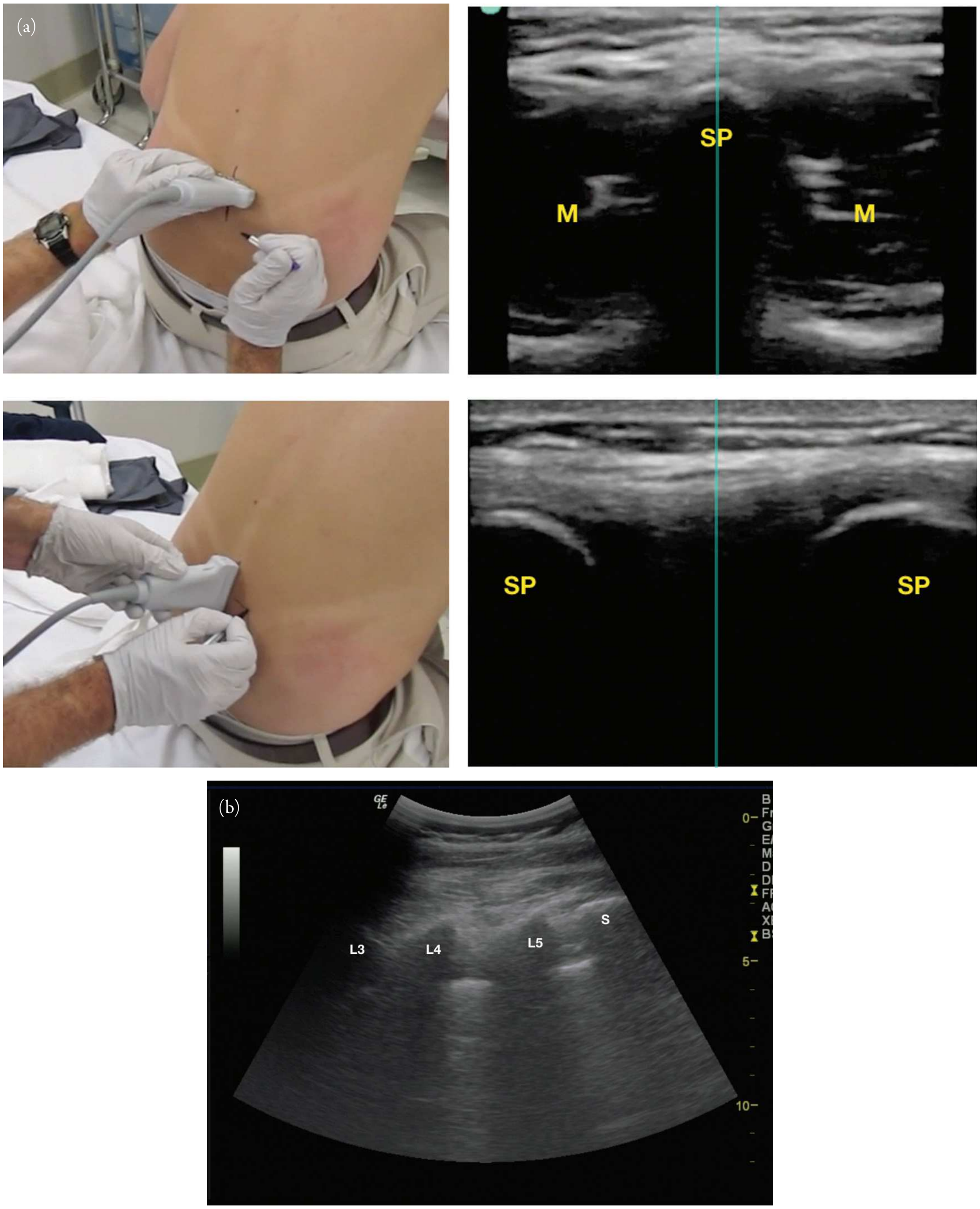

Figure 13.20 (a) **Ultrasound-assisted lumbar puncture technique.** (b) **Spine anatomy for lumbar puncture.** Shows 3rd through 5th lumbar spine intraarticular processes (L3, L4, L5) and sacrum (S).

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Keywords/Tags: Lumbar puncture

Learning Point 7: Ultrasound guided lumbar puncture

8. EXPLANATION

C. Deep abrasion to the lateral thigh. A femoral nerve block is an excellent choice for multiple injuries of the leg. It will provide anesthesia and motor blockage to the anterior and medial thigh and the medial portion of the lower leg

down to the foot via blockade of the saphenous nerve. The femoral nerve lies lateral to the femoral artery and vein, on top of the iliopsoas muscle in the inguinal region (Figure 13.21). Theoretically local anesthetic injected at the inguinal level will track cephalad, medial, and laterally to affect the distal anterior branch of the obturator nerve and the lateral femoral cutaneous nerve in addition to the femoral nerve, sometimes referred to as a "3-in-1" block. However, reliable blockade of the lateral femoral cutaneous nerve is not always achieved. As with all nerve blocks, discussion should take place with consulting services prior to the procedure, and blocks should not be performed in patients with neuro deficits or those at high risk of compartment syndrome, including tibia-fibula fractures.

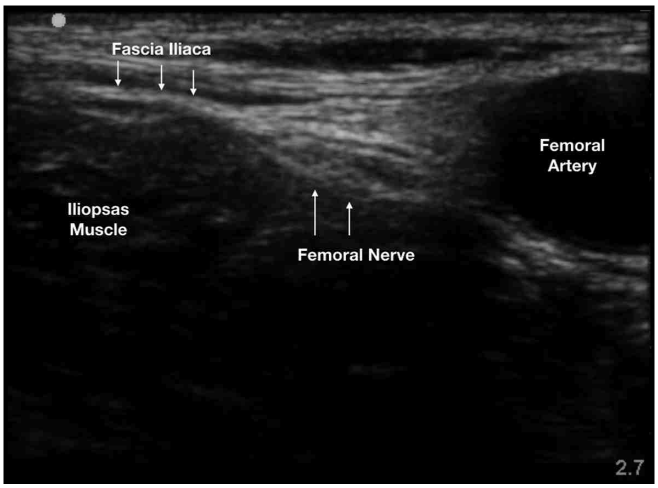

Figure 13.21 **Identification of femoral nerve and fascia iliaca.**

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Keywords/Tags: Femoral nerve block, regional anesthesia

Learning Point 8: Femoral nerve blocks provide anesthesia to the anterior and medial thigh and lower leg.

9. EXPLANATION

C. Endocavitary probe, supraclavicular. Ultrasound-guided approach to the subclavian vein is challenging due to the degree of overlap of the artery and vein, increased depth of the vessels in the infraclavicular view, and the limited space in the supraclavicular view, prohibiting probe footprint placement. A novel in-plane approach using the endocavitary probe in the supraclavicular space showed promising results for anatomy identification and needle guidance (Figure 13.22). Additional reports suggest a supraclavicular approach to the subclavian vein using a smaller footprint probe such as the microconvex or "hockey stick," could also potentially fit into the supraclavicular space. More studies need to be done to evaluate this technique further.

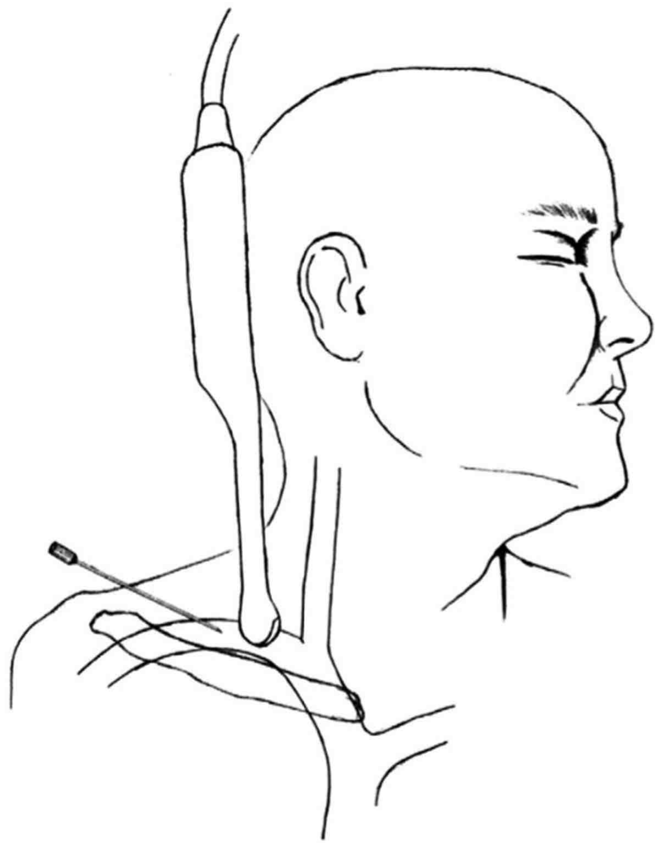

Figure 13.22 Ultrasound guided supraclavicular approach to subclavian vein using an endocavitary probe. Adapted from Figure 2 of Mallin M, Louis H, Madsen T. A novel technique for ultrasound-guided supraclavicular subclavian cannulation. *Am J Emerg Med*. 2010;28(8):966–969. doi:10.1016/j.ajem.2009.07.019.

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Keywords/Tags: Subclavian, transducer choice

Learning Point 9: A supraclavicular approach to subclavian vein cannulation can be considered when the chest is inaccessible and the IJV is not an option.

10. EXPLANATION

A. 1. Fascia iliaca 2 = femoral nerve, 3 = femoral artery, and 4 = muscle/fascia lata. In a FICB, local anesthetic is deposited beneath the fascia iliaca at the inguinal level, lateral to the femoral neurovascular bundle, keeping the needle away from the vasculature. The anesthetic will diffuse through the compartment and eventually surround the femoral nerve, potentially extending proximally and laterally to the obturator and lateral femoral cutaneous nerves. This effect may be encouraged in a femoral nerve block as well by placing pressure distal to the injection site during the procedure. Theoretically, there may be less motor blockade in a FICB compared to a femoral nerve block because a larger volume of a lower concentration of anesthetic is generally used. When compared to an ultrasound-guided "3-in-1" femoral nerve block, the FICB showed similar analgesic effect.

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Keywords/Tags: Fascial iliaca compartment block, regional anesthesia

Learning Point 10: In a fascia iliaca compartment block (FICB), local anesthetic is deposited beneath the fascia iliaca at the inguinal level, lateral to the femoral neurovascular bundle.

11. EXPLANATION

B. B. For all ultrasound-guided procedures, the ultrasound screen should be in the proceduralist's direct eyeline to minimize head-turning and overmovement, which will make the procedure more difficult and prone to error. Depending on the dominant hand of the clinician as well as the location of the cardiac monitor, the ultrasound machine should be placed in either A, C, or D. B is incorrect because the clinician would have to turn his or her head away to see the screen. Care should be taken to position oneself to be able to visualize the field, ultrasound screen, and cardiac monitor all without requiring much movement.

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Keywords/Tags: Procedural set-up, preparation

Learning Point 11: For all ultrasound-guided procedures the ultrasound screen should be in the proceduralist's direct visual line to minimize head-turning and overmovement, which will make the procedure more challenging to perform.

12. EXPLANATION

D. Radial nerve forearm block. The wrist joint and distal forearm have complicated periosteal and cutaneous innervation, with sensory and motor supply from the radial, median, and ulnar nerves as well as the musculocutaneous nerve (Figure 13.23a, Figure 13.23b, Figure 13.23c). As such, the nerves must be blocked proximal to their bifurcation into their motor and sensory branches. This can be achieved by blocking the brachial plexus in the supraclavicular, infraclavicular or axillary regions. For an isolated distal radius fracture, the radial nerve can be blocked in the supracondylar space above the forearm to achieve motor and sensory anesthesia.

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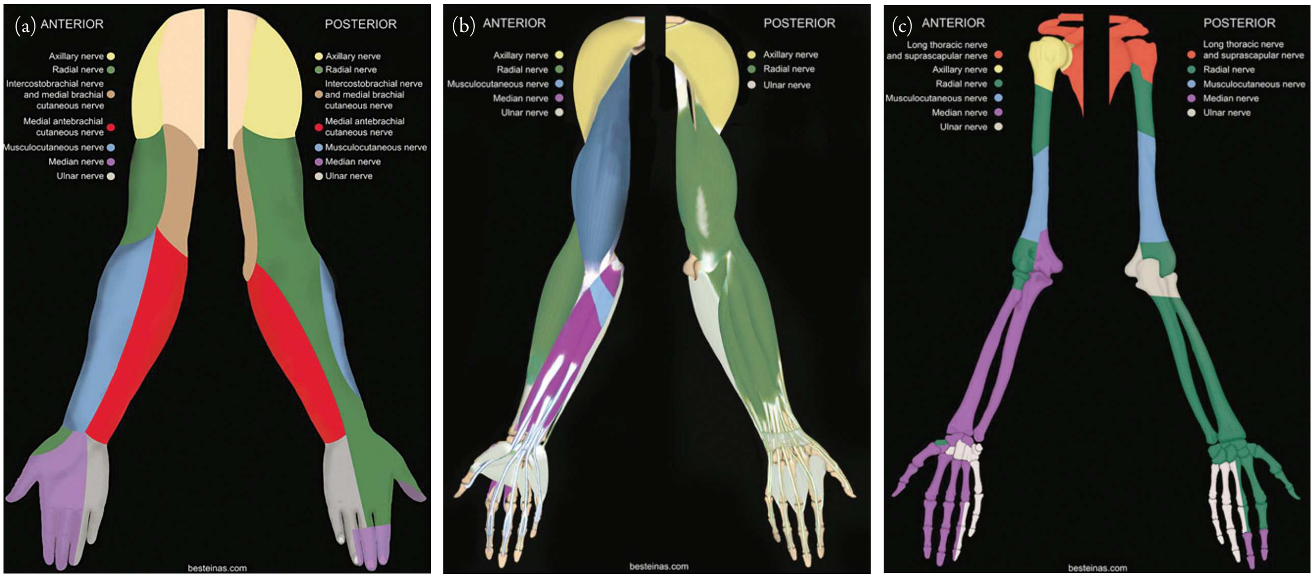

Figure 13.23 (a) **Upper extremity nerve territories for dermatomes.** Adapted from Figure 1 of Nadeau M-J, Lévesque S, Dion N. Anesthésie locorégionale échoguidée pour la chirurgie du membre supérieur. *Can J Anesth/J Can Anesth.* 2013;60(3):304–320. doi:10.1007/s12630-012-9874-6. (b) **Upper extremity nerve territories for muscle (myotomes).** (c) **Upper extremity nerve territories for bones (sclerotomes).**

Keywords/Tags: Regional anesthesia, distal radius fracture

Learning Point 12: To achieve anesthesia of the wrist, the brachial plexus should be blocked at the supraclavicular, infraclavicular or axillary level.

13. EXPLANATION

D. Femoral vein. This is an appropriate initial choice in the resuscitation of a critically ill patient for a few different reasons: it does not interrupt CPR, airway management, or maintenance of a c-collar; there is no risk of an iatrogenic pneumothorax; and the vessel does not collapse with volume depletion. During CPR, it is important to note that the vein may be the pulsatile vessel given the backflow of blood from chest compressions causing the femoral vein to appear pulsatile relative to the artery (Hilty et al. 1997). If using ultrasound, remember that the femoral vein is medial to the femoral artery. The primary relative contraindication for ultrasound-guided femoral venous cannulation in trauma is when there is suspected intraabdominal vascular injury.

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Keywords/Tags: Femoral line, central venous access, trauma, critical care

Learning Point 13: In a critically ill patient who cannot lay flat due to dyspnea or who has a c-collar after a trauma, a femoral line is an appropriate initial choice for rapid central venous access.

14. EXPLANATION

C. Curvilinear probe, in-plane. For dynamic needle visualization during an ultrasound-guided pericardiocentesis, use the curvilinear probe and obtain a parasternal long axis view to identify the effusion. Insert the needle in an in-plane approach and visualize it entering the pericardial space (Figure 13.24). Once fluid is successfully aspirated, advance the guidewire and, using the Seldinger technique, slide the catheter over the wire into the space, allowing for continued drainage.

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Keywords/Tags: Pericardiocentesis, tamponade, Seldinger technique

Figure 13.24 **Pericardiocentesis using a curvilinear transducer and in-plane technique with visualization of the needle entering the pericardial space.**

Learning Point 14: When performing a pericardiocentesis, find the parasternal long axis view using a curvilinear probe and do the procedure using an in-plane approach with Seldinger catheter over wire technique.

Learning Point 15: After a successful ultrasound-guided pericardiocentesis, repeat ultrasound examination can confirm reduction in the amount of pericardial fluid as well as increase in IVC respiratory variability.

15. EXPLANATION

A. Decreased size or resolution of the pericardial effusion and increase in IVC variability. Once a pericardial effusion is adequately drained, you can visualize a reduction in the effusion size with your bedside cardiac ultrasound. In tamponade, pericardial effusions prevent the ventricles from filling adequately, and, as a result, there is a backup of flow causing a plethoric IVC with no respiratory variation. After successfully draining an effusion, you can use your bedside ultrasound to observe the return of respiratory variability to the IVC. The right ventricular free wall should not collapse further if an effusion is drained, and chamber size should not decrease after a pericardiocentesis.

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Keywords/Tags: Pericardiocentesis, tamponade

16. EXPLANATION

B. Inability to visualize the needle in plane and necessity of traversing the liver. There is a slightly higher risk of pneumothorax when performing a pericardiocentesis using an apical approach. When performing the procedure using a parasternal long approach, there is an increased risk of injuring the internal mammary vessels. Myocardial injury and other vascular (including coronary) injury are complications regardless of the approach. With the subxiphoid approach specifically, because of the angle required, the procedure cannot be done with in-plane needle visualization, and the left lobe of the liver may be traversed either intentionally or unintentionally (but the risk of significant liver injury is still low).

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Keywords/Tags: Pericardiocentesis, tamponade

Learning Point 16: The subxiphoid approach for pericardiocentesis is more challenging because the needle cannot be visualized in plane and the liver may be traversed (intentionally or unintentionally).

17. EXPLANATION

A. Phased array probe, patient sitting up. Ultrasound guidance in thoracentesis reduces the risk of pneumothorax from as high as 30% to less than 3% (Feller-Kopman 2006). In stable patients, when they sit forward, the dependent fluid is easily visualized with a posterior approach using either a linear or phased array probe (Figure 13.25). In critically ill or intubated patients, it is often not feasible to have the patient upright. Thoracentesis may still be performed with the patient about 30 degrees recumbent, using a posterior-lateral approach (Soldati et al. 2013).

To identify an appropriate target to tap, place the probe medial to the scapula and over the intercostal spaces to identify the hypoechoic fluid in multiple planes (anterior-posterior and superior-inferior). Two main criteria for an appropriate space should be considered:

- It should be the most inferior pocket that has a fluid collection that is at least 1.5 cm deep.
- The diaphragm or lung should not be visualized at this level to avoid inadvertent puncture of either structures.

The procedure can be performed using real-time ultrasound guidance or with the use of ultrasound to identify an appropriate space prior to sterilization of the field. If the latter approach is used, ensure that the patient maintains the same positioning, as the ultrasound landmarks will change if patient's position changes.

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Keywords/Tags: Thoracentesis, pleural effusion

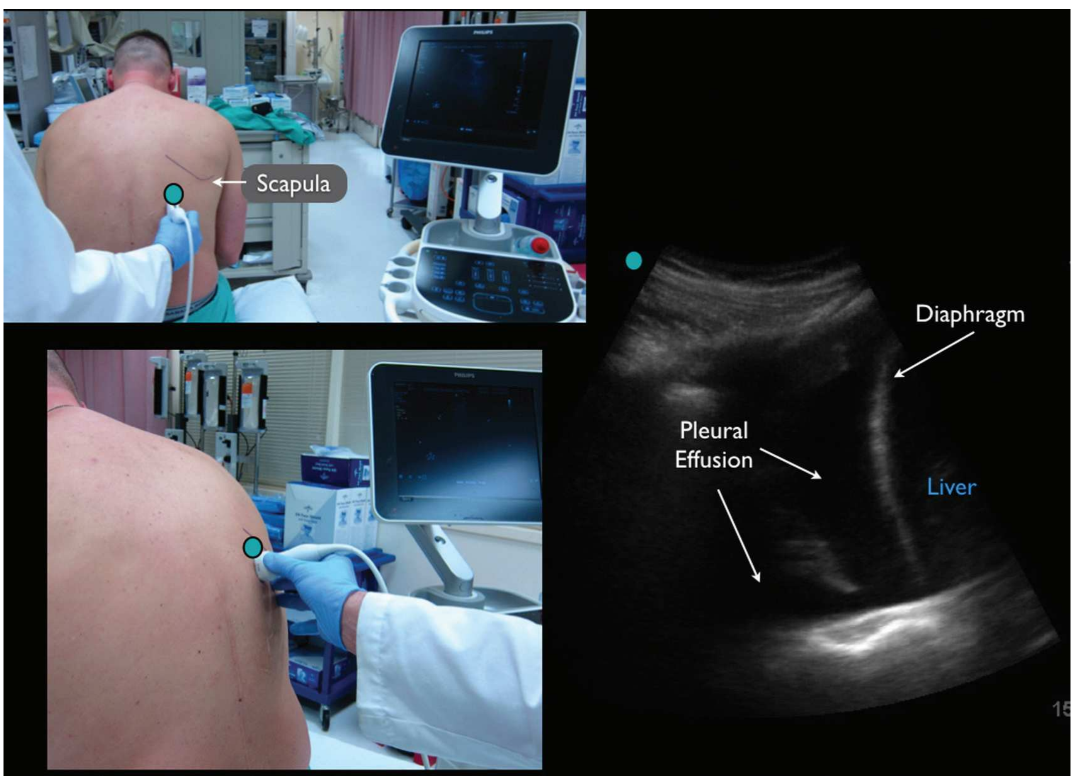

Figure 13.25 **Proper positioning of patient with transducer indicator toward the head for evaluation of pleural effusion and preparation for thoracentesis.**

Learning Point 17: To perform a thoracentesis, the patient should be seated and leaning forward, and the phased array transducer identifies the deepest pocket of fluid when placed over the intercostal spaces.

18. EXPLANATION

D. D. Figure 13.7 has the corresponding findings: A = lung, B = liver, C = pleural effusion, D = diaphragm. The diaphragm is visualized as a hyperechoic linear structure on ultrasound that should be identified before performing a thoracentesis as an important landmark that divides the thoracic and abdominal cavities. In general, a thoracentesis can be performed safely at or above the ninth intercostal space with minimal risk of a diaphragmatic or abdominal injury. Keep in mind that the diaphragm is a domed structure that moves with respirations, so that while fluid may be seen below the ninth intercostal space, needle insertion below this level carries a risk of diaphragm puncture. Pleural effusions are generally hypoechoic collections located cephalad to the liver and diaphragm, and the collapsed lung is often visualized floating in the effusion.

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Keywords/Tags: Pleural effusion, thoracentesis

Learning Point 18: While performing a thoracentesis, identifying the diaphragm as the hyperechoic lower margin of the thoracic cavity can ensure avoidance of inadvertently entering the abdominal cavity.

19. EXPLANATION

B. Presence of loculations and septations. Homogenous hypoechoic/anechoic pleural effusions are more likely to be transudative effusions and more easily aspirated via bedside thoracentesis. However, if the effusion is loculated/heterogeneous/septated, it is more likely to be an empyema, mass, or clot that needs surgical intervention. The plankton sign is a finding that refers to the presence of dynamic echogenic debris within the effusion suggestive of an exudate. The hematocrit sign is the presence of a layer of cellular debris in the dependent component of the effusion also suggestive of an exudate.

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Keywords/Tags: Thoracentesis, loculated pleural effusion, septated pleural effusion

Learning Point 19: Before performing a thoracentesis, the pleural fluid should be examined—if it is hypoechoic and homogenous, it is more likely to be successfully aspirated. If the fluid is more heterogenous, septated, or hyperechoic, this is more indicative of an empyema or mass or blood/clot that will need thoracic surgical intervention.

20. EXPLANATION

D. None of the above. Forearm nerve blocks are very effective in analgesia for fractures, lacerations, and for incision and drainage of abscesses in the hand (Figure 13.26). However, they are not adequate for pathology of the forearm and wrist. A more proximal nerve block involving the supraclavicular, infraclavicular, or axillary portion of the brachial plexus would be effective for forearm and wrist pathology (Table 13.1).

Figure 13.26 **Forearm nerve distributions.**

Table 13.1 **INDICATIONS, ADVANTAGES, AND DISADVANTAGES OF COMMON UPPER LIMB BLOCKS**

PERIPHERAL NERVE BLOCK	INDICATIONS	ADVANTAGES	DISADVANTAGES
Interscalene brachial plexus block	Any pathology involving the shoulder or proximal humerus	Superficial Comfortable for patient	Hemidiaphragmatic paralysis Often does not block inferior trunk and not recommended for elbow, forearm, or hand pathology
Supraclavicular brachial plexus block	Any arm pathology distal to the shoulder	Anesthesia of all portions of the arm distal to the shoulder Fast onset and simple to perform	Potential for pneumothorax, vascular injury due to proximity to subclavian vessels, and hemidiaphragmatic paralysis
Infraclavicular brachial plexus block	Any arm pathology distal to the axilla	Anesthesia to the entire arm distal to the axilla Does not affect phrenic nerve	Deeper block Greater discomfort to patient Requires more expertise Potential risk for pneumothorax
Axillary brachial plexus block	Any pathology of the elbow or distal to the elbow.	No risk of pneumothorax, neuraxial block, or phrenic nerve blockade	Hematoma if using transarterial technique Site of injection can be tender after anesthetic wears off
Distal forearm blocks of the median, ulnar, and radial nerves (at elbow or forearm)	Hand pathology	Avoids motor block of upper extremity muscles Lower dose of local anesthetic required	Procedures on lateral forearm/wrist will require separate blockade of either lateral cutaneous nerve or musculocutaneous nerve

REFERENCES

Liebmann O, Price D, Mills C, Gardner R, Wang R, Wilson S, Gray A. Feasibility of forearm ultrasonography-guided nerve blocks of the radial, ulnar, and median nerves for hand procedures in the emergency department. *Ann Emerg Med*. 2006 Nov 30;48(5):558–562.

McCartney CJ, Xu D, Constantinescu C, Abbas S, Chan VW. Ultrasound examination of peripheral nerves in the forearm. *Reg Anesth Pain Med*. 2007 Sep 30;32(5):434–439.

Milligan R, Houmes S, Goldberg LC, Nagdev A, Amini R. Ultrasound-guided forearm nerve blocks in managing hand and finger injuries. *Intern Emerg Med*. 2017 Apr 1;12(3):381–385.

Wroe P, O'Shea R, Johnson B, Hoffman R, Nagdev A. Ultrasound-guided forearm nerve blocks for hand blast injuries: case series and multidisciplinary protocol. *Am J Emerg Med*. 2016 Sep 1;34(9):1895–1897.

Keywords/Tags: Forearm nerve block, regional anesthesia

Learning Point 20: Forearm nerve blocks are useful for various pathologies of the hand—fractures, abscesses, lacerations—but they are not adequate for injuries of the wrist or forearm.

21. EXPLANATION

B. Ulnar nerve block. Ultrasound-guided nerve blocks on the forearm can be performed on the ulnar, median, and radial nerves (Figure 13.27a). The patient in this vignette has suffered a boxer's fracture—a fracture to the neck of his metacarpal bone. Blocking the ulnar nerve at the level of the forearm will adequately anesthetize the fifth digit for this type of injury. Positioning of the patient's arm for an ulnar nerve block can be seen in Figure 13.27b. The radial and median nerves also can be blocked in the forearm but provide anesthesia more radially to the dorsal and volar aspects of the hand, respectively. The axillary nerve does not travel in the forearm and supplies sensation over the deltoid.

REFERENCES

Gray AT, Schafhalter-Zoppoth I. Ultrasound guidance for ulnar nerve block in the forearm. *Reg Anesth Pain Med*. 2003 Aug 31;28(4):335–339.

Liebmann O, Price D, Mills C, et al. Feasibility of forearm ultrasonography-guided nerve blocks of the radial, ulnar, and median nerves for hand procedures in the emergency department. *Ann Emerg Med*. 2006 Nov 30;48(5):558–562.

Keywords/Tags: Ulnar nerve block, regional anesthesia, hand injuries

Learning Point 21: For a boxer's fracture and other injuries to the fifth digit, an ulnar nerve block in the forearm should provide adequate anesthesia.

22. EXPLANATION

B. Median nerve between the flexor digitorum superficialis and the flexor digitorum profundus at the midforearm. The injury described here lies in the sensory distribution of the median nerve. A median nerve block at

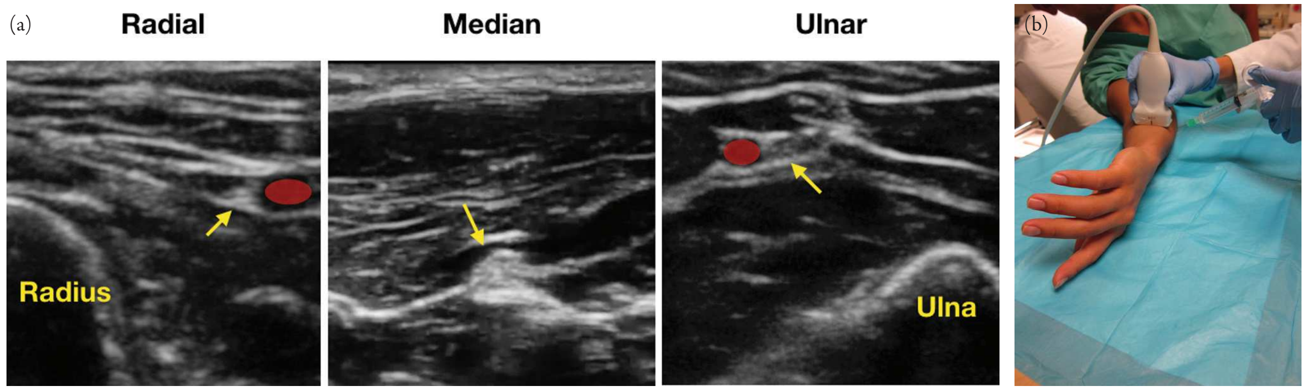

Figure 13.27 (a) **Ulnar, median, and radial nerves (arrow) and arteries (red discs) in the forearm.** (b) **Patient positioning for ulnar nerve block.**

the carpal tunnel will be difficult to perform on ultrasound, as the surrounding tendons will be virtually indistinguishable from the median nerve. In addition, sensory fibers of the nerve may divide off more proximally, thus rendering only a partial sensory block.

Figure 13.28a shows correct patient positioning to perform a median nerve block using the in-plane approach. While performing an ultrasound-guided forearm block, the median nerve can be identified as a honeycomb structure in the mid-forearm between the FDS and FDP muscles (Figure 13.28b). The superficial branches of the radial nerve and the ulnar nerve can be identified adjacent to their respective arteries (Figure 13.27a).

REFERENCES

Gray AT, Schafhalter-Zoppoth I. Ultrasound guidance for ulnar nerve block in the forearm. *Reg Anesth Pain Med*. 2003 Aug 31;28(4):335–339.

Liebmann O, Price D, Mills C, et al. Feasibility of forearm ultrasonography-guided nerve blocks of the radial, ulnar, and median nerves for hand procedures in the emergency department. *Ann Emerg Med*. 2006 Nov 30;48(5):558–562.

Keywords/Tags: Regional anesthesia, forearm nerve block, median nerve

Learning Point 22: The median nerve is identified in cross-section at the mid-forearm near midline between the flexor digitorum superficialis (FDS) and flexor digitorum profundus (FDP).

23. EXPLANATION

A. Linear probe, transverse orientation. The superficial branches of the radial nerve, the median nerve, and the ulnar nerve are superficial structures best identified as small honeycomb shaped structures with the linear probe placed

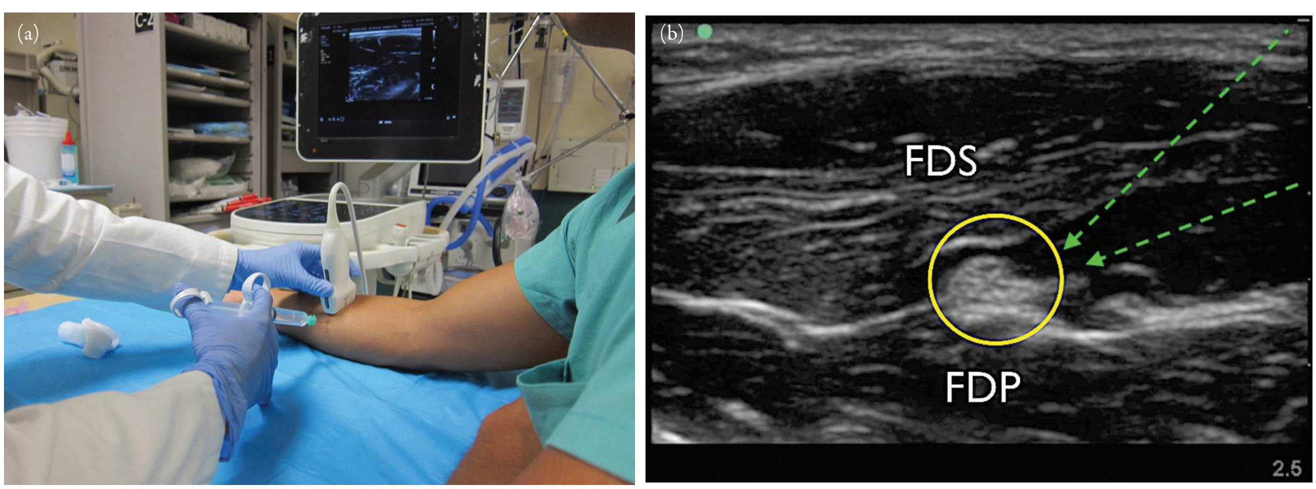

Figure 13.28 (a) **Patient positioning for the median nerve block using an in-plane approach.** (b) **Median nerve block.** The median nerve is outlined in yellow. The green dashed arrows show possible needle trajectories for the procedure. FDS = flexor digitorum superficialis; FDP = flexor digitorum profundus.

transversely over the forearm. The superficial radial nerve can be found adjacent to the radial artery and is blocked using an in-plane approach (Figure 13.29).

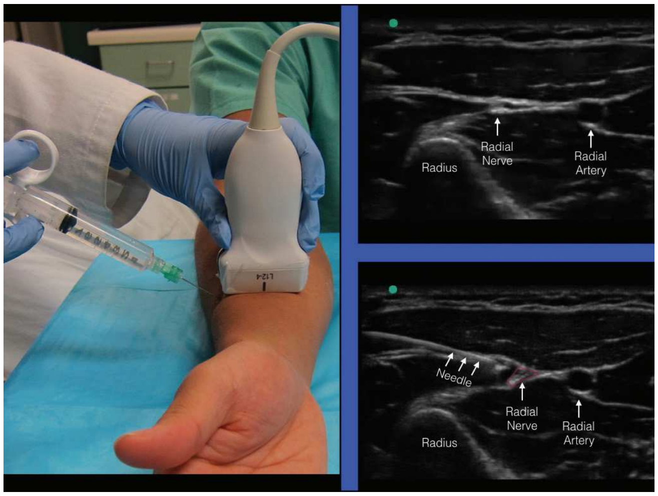

Figure 13.29 **Patient positioning and ultrasound guidance for the radial nerve block using an in-plane approach.**

REFERENCES

Gray AT, Schafhalter-Zoppoth I. Ultrasound guidance for ulnar nerve block in the forearm. *Reg Anesth Pain Med*. 2003 Aug 31;28(4):335–339.

Liebmann O, Price D, Mills C, et al. Feasibility of forearm ultrasonography-guided nerve blocks of the radial, ulnar, and median nerves for hand procedures in the emergency department. *Ann Emerg Med*. 2006 Nov 30;48(5):558–562.

Keywords/Tags: Regional anesthesia, forearm nerve block, radial nerve

Learning Point 23: The radial nerve is identified by placing the linear high-frequency probe transversely over the forearm — once the radial artery is identified, the superficial branch of the radial nerve is found radial to the vessel. The block is performed using an in-plane approach.

24. EXPLANATION

C. Weakness in extensor muscles of the hand. Only the superficial branch of the radial nerve is blocked in the forearm. The radial nerve is larger and more readily identified at the level of elbow, but a nerve block here affects both the superficial and deep branches of the nerve. The deep branch provides motor innervation to the extensor muscles in the hand and wrist and becomes the posterior interosseous nerve in the forearm. Therefore, blocking the nerve at the level of the elbow would result not just in sensory loss over the dorsum of the hand but also in some extensor weakness.

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Keywords/Tags: Regional anesthesia, nerve block, radial nerve

Learning Point 24: The radial nerve can also be identified and blocked just above the elbow and near the supracondylar region—it is found radially just along the hyperechoic humerus and is larger in size compared to nerve at the distal forearm.

25. EXPLANATION

B. Serratus anterior plane block. The serratus anterior plane block targets the cutaneous branches of the lateral intercostal nerves, which emerge between the grooves of the serratus anterior muscle in the mid-axillary line. The block is performed using a linear high-frequency transducer where a large volume of local anesthetic is infused in the fascial plane where the nerves travel (Figure 13.30)

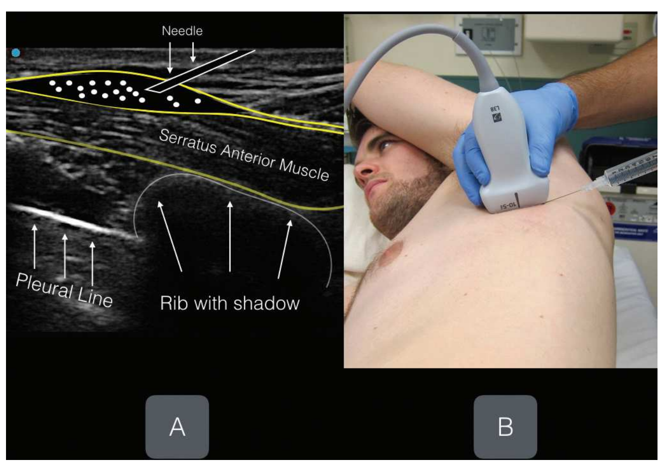

Figure 13.30 **Serratus anterior plane block.**

and provides effective analgesia for anterior and lateral rib fractures without compromising respiratory drive. The erector spinae block is more effective for posterior rib fractures.

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Blanco R, Parras T, McDonnell JG, Prats-Galino A. Serratus plane block: a novel ultrasound-guided thoracic wall nerve block. *Anaesthesia*. 2013 Nov 1;68(11):1107–1113.

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Keywords/Tags: Rib fracture, regional anesthesia, serratus anterior plane block

Learning Point 25: The serratus anterior plane block is performed in plane using the linear high-frequency transducer at the mid-axillary line to target the cutaneous branches of the intercostal nerves and provides effective analgesia without compromising respiratory drive in patients with multiple lateral and anterior rib fractures.

26. EXPLANATION

D. Below the rib (between the rib and pleural line). Local anesthetic can be deposited in the plane either directly above the serratus muscle or below the muscle just above the rib for an effective serratus anterior plane block. However, care must be identified to clearly identify the rib and the pleural line, because there still is a risk of an iatrogenic pneumothorax if performed incorrectly.

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Blanco R, Parras T, McDonnell JG, Prats-Galino A. Serratus plane block: a novel ultrasound-guided thoracic wall nerve block. *Anaesthesia*. 2013 Nov 1;68(11):1107–1113.

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Serratus plane blocks for rib fractures. In: Herring A, ed. *Highland EM Ultrasound Fueled Pain Management*. 2017. http://highlandultrasound.com/rib-fractures/.

Keywords/Tags: Regional anesthesia, serratus anterior plane block

Learning Point 26: Local anesthetic can be deposited either directly over or under the serratus muscle to achieve a serratus anterior plane block.

27. EXPLANATION

C. Perform a transversus abdominis plane block. The patient is apparently experiencing side effects from the opiate-based pain medication he was prescribed, and increasing his dose will likely exacerbate his constipation without providing much more pain relief. An enema is an option for severe constipation but will not address his postoperative pain. The transversus abdominis plane block is an ultrasound-guided regional block performed using a linear high-frequency transducer to deposit local anesthetic in the plane between the internal oblique fascia and transversus abdominis muscle (Figure 13.31). It is performed in-plane in the mid-axillary line between the subcostal margin and the iliac crest and targets the nerves providing sensory innervation to the abdominal wall. This is a procedure that can be not only very effective in postoperative pain control but can reduce the use of opiates and their associated adverse effects. Note that there is some controversy regarding the extent of this block, with many studies reporting inadequate blockade of the abdominal wall above the umbilicus (T7–T9). However, it reliably blocks the level at the umbilicus and below to the groin (T10–L1), and bilateral blocks can be performed for pain at the midline.

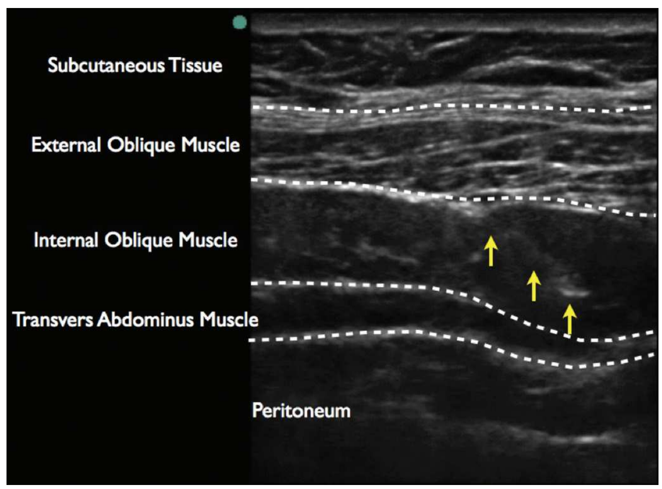

Figure 13.31 **Tranversus abdominis plane block.** Yellow arrows point to needle.

REFERENCES

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Keywords/Tags: Regional anesthesia, transversus abdominis plane block

Learning Point 27: In a patient who is post-op after abdominal surgery, the transversus abdominis plane block can provide effective regional anesthesia. The block is performed in-plane (using the linear transducer) in the mid-axillary line between the iliac crest and the subcostal margin by depositing local anesthetic between the internal oblique muscle and the transversus abdominis muscle.

28. EXPLANATION

C. Stop the procedure and ultrasound the chest to look for a pneumothorax. A pneumothorax is a possible complication when placing a central line in either the internal jugular or subclavian veins. If a patient either complains of chest pain and shortness of breath during the procedure or you observe oxygen desaturation, your bedside ultrasound can quickly assess for a pneumothorax. Use the linear probe and look for the absence of pleural sliding on the side of the line insertion. Ultrasound is more sensitive for identifying pneumothorax than chest X-ray, especially in a supine patient (Volpicelli 2011). If the patient is unstable, the procedure should not be continued (A is incorrect). A CT scan is also inappropriate for the same reason, unless the patient is stabilized first (B is incorrect). Though myocardial infarction is in the differential, ruling out pneumothorax quickly is the next best step (D is incorrect).

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Keywords/Tags: Central venous access, pneumothorax, critical care

Learning Point 28: If a patient suddenly complains of chest pain or shortness of breath, or desaturation is observed while performing a central line using ultrasound guidance, stop the procedure and use the ultrasound to check the lungs for evidence of a pneumothorax (absent lung sliding).

29. EXPLANATION

C. Posterior tibial nerve block. The posterior tibial neve block provides innervation to the most of the sole of the foot (Figure 13.32). It is performed just posterior to the medial malleolus where the posterior tibial nerve travels with the posterior tibial artery and vein. The femoral nerve innervates the anterior thigh and medial portion of the lower leg. The saphenous nerve (distal branch of the femoral nerve) innervates a small region of the medial sole of the foot. The sural nerve innervates a small portion of the lateral aspect of the sole of the foot. The lateral femoral cutaneous nerve innervates the lateral aspect of the thigh. With the posterior tibial nerve block, the patient will lose sensation to the plantar aspect of the foot but retain motor function at the ankle and toes.

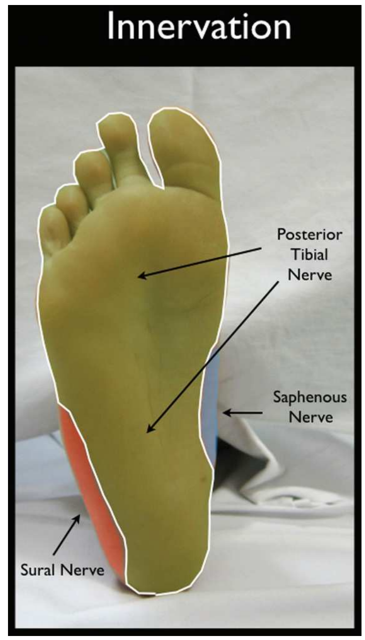

Figure 13.32 **Foot innervation distribution of posterior tibial nerve, saphenous nerve, and sural nerve.**

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Soares LG, Brull R, Chan VW. Teaching an old block a new trick: ultrasound-guided posterior tibial nerve block. *Acta Anaesthesiol Scand*. 2008 Mr; 52(3):446–447.

Learning Point 29: Posterior tibial nerve blocks provide analgesia for calcaneal fractures. With this block the patient will lose sensation to the sole of foot but retain motor function at the ankle and toes.

30. EXPLANATION

D. Laceration to medial lower leg. The distal sciatic nerve block provides anesthesia to the posterior knee, hamstring

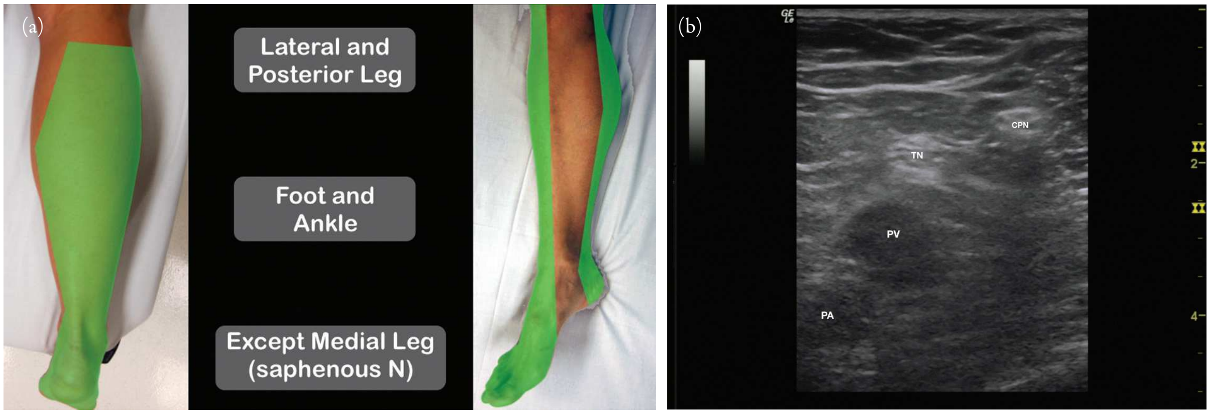

Figure 13.33 (a) **Sciatic nerve distribution.** (b) **Popliteal nerve block.** CPN = common peroneal nerve; TN = tibial nerve; PV = popliteal vein; PA = popliteal artery.

muscles, and entire lower leg below knee and results in both motor and sensory blockake (Figure 13.33a), with the exception of the skin of the medial lower leg and ankle—these areas are innervated by the saphenous nerve. The patient should be placed in prone position if possible, and an in-plane lateral to medial approach is suggested. The goal is to place the needle tip at the level of the bifurcation of the distal sciatic nerve where the posterior tibial nerve and the common peroneal nerve originate (Figure 13.33b).

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Learning Point 30: The ultrasound-guided distal sciatic nerve block can provide good analgesia for injuries of the distal leg and ankle. However, this block will not provide anesthesia to superficial areas of the medial lower leg and ankle because these areas are innervated by the saphenous nerve.

31. EXPLANATION

D. All of the above. The nerve is barely visible in the figure. Tilting the probe to become perpendicular to the nerve will allow better visualization of the nerve. This property of ultrasound is called anisotropy (Figure 13.34, Video 13.5). Identification of the popliteal vein and artery (often located just deep to the distal sciatic nerve) can help with orientation and easier identification of the nerve. Also, passive or active dorsiflexion/plantarflexion of the ipsilateral foot will move the two distal branches of the sciatic nerve (posterior tibial and peroneal) and assist in easier sonographic recognition.

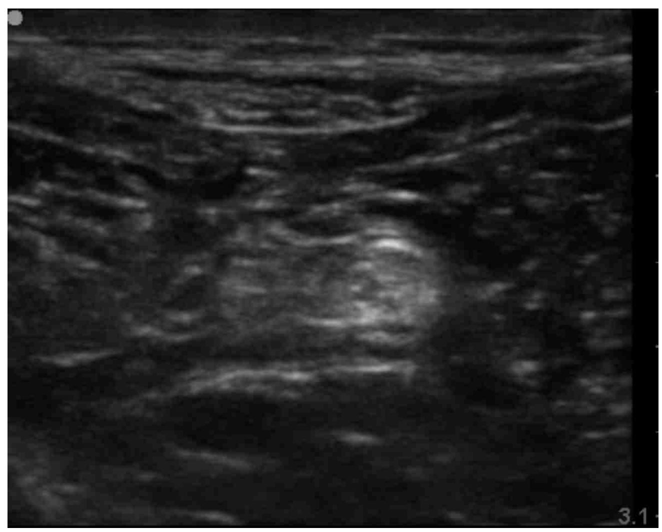

Figure 13.34 **Sciatic nerve easily visualized since probe is perpendicular to the nerve.** A property called anisotropy.

REFERENCE

Schafhalter-Zoppoth I, Younger SJ, Collins AB, Gray AT. The "see-saw" sign: improved sonographic identification of the sciatic nerve. *Anesthesiology*. 2004;101(3):808–809.

Learning Point 31: To easily identify the sciatic nerve, first visualize it with the popliteal vein and artery in the popliteal fossa, and then follow it proximally.

32. EXPLANATION

D. Intralipid. Local anesthetic toxicity syndrome occurs from intravascular injection of local anesthetic. Intralipid should be administered as a bolus at 1.5 mL/kg and then a drip at 0.25 mL/kg/min for persistent cardiovascular collapse. This is in addition to supportive care, advanced cardiac life support (ACLS), and anticonvulsants as needed.

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Keywords/Tags: Local anesthetic systemic toxicity, regional anesthesia, pitfalls

Learning Point 32: Treatment of local anesthetic toxicity is treated with intralipid.

33. EXPLANATION

C. Reattempt your reduction. The image shows that the humeral head is clearly anteriorly dislocated relative to the glenoid and has not been successfully reduced. Given that the patient does not have a concomitant fracture or history of recurrent dislocations, it is appropriate to try to continue to reduce the shoulder in the ED. While the patient is still blocked/sedated, point of care shoulder ultrasound can quickly alert the ED provider if the reduction attempt was unsuccessful while awaiting a post-reduction film that often is delayed or sometimes difficult to interpret.

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Keywords/Tags: Shoulder dislocation, shoulder reduction

Learning Point 33: Point of care ultrasonography of the shoulder can not only help the ED provider diagnose shoulder dislocations, but it can also be used to as a real-time tool to check whether a reduction attempt is successful while awaiting a post-reduction film.

34. EXPLANATION

B. Place her in a sugar-tong forearm splint now. The image shows a longitudinal view of the distal radius with a clear fracture line (Figure 13.35). Note that there is minimal displacement of the fractured segment and reasonably good alignment. Point of care ultrasonography of distal radius fractures is a simple, minimally invasive tool that allows a rapid assessment of reduction adequacy. Plain films may not be readily available and waiting on an x-ray after reduction attempts may cause unnecessary delay as the patient's block or sedation wears off. The ultrasound can clearly and quickly show whether there is still a large degree of displacement or misalignment that needs further correction prior to splinting and confirmatory films.

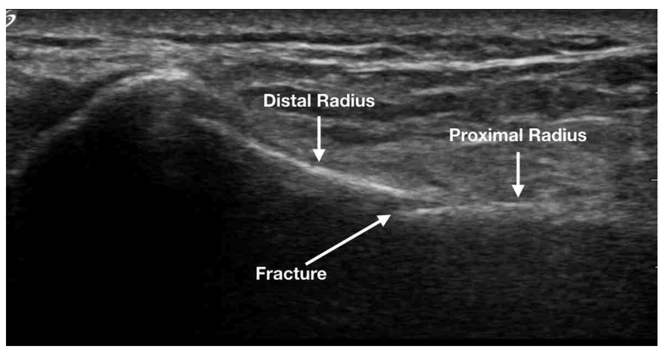

Figure 13.35 **Distal radius fracture with good alignment and minimal displacement.**

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Keywords/Tags: Distal radius fractures, fracture reduction

Learning Point 34: Ultrasound can be used at the bedside to evaluate whether the reduction of a distal radius fracture is satisfactory before applying a splint and waiting for the post-reduction film.

35. EXPLANATION

B. B. Figure 13.11 corresponding structures: A = thyroid cartilage, B = cricothyroid membrane, C = cricoid cartilage, D = tracheal ring. Emergent cricothyrotomy is a rare but life-saving procedure that is high-stress and high-stakes in a critically ill patient who is already not being oxygenated or ventilated adequately. Several studies show that palpation of landmarks is unreliable, particularly in obese patients or those with a significant amount of distortion of the anterior neck. Using the linear high frequency transducer in a longitudinal orientation, the ED provider can find the cricothyroid membrane and its posterior reverberating artifact between the hyperechoic thyroid and cricoid cartilage (both of which have an associated posterior acoustic shadow). The cricothyroid membrane can be identified and marked in preparation for a difficult airway, and serve as a back-up in case the intubation is unsuccessful.

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Mallin M, Curtis K, Dawson M, Ockerse P, Ahern M. Accuracy of ultrasound-guided marking of the cricothyroid membrane before simulated failed intubation. *Am J Emerg Med*. 2014 Jan 1;32(1):61–63.

Siddiqui N, Arzola C, Friedman Z, Guerina L, You-Ten KE. Ultrasound improves cricothyrotomy success in cadavers with poorly defined neck anatomy a randomized control trial. *Anesthesiology*. 2015 Nov 1;123(5):1033–1041.

Teoh WH, Kristensen MS. Ultrasonographic identification of the cricothyroid membrane. *Anaesthesia*. 2014 Jun 1;69(6):649–650.

Keywords/Tags: Cricothyrotomy, advanced airway, airway anatomy

> **Learning Point 35:** When preparing for an emergent cricothyrotomy, ultrasound can assist in identifying airway landmarks in patients with challenging surface anatomy.

36. EXPLANATION

D. Ultrasound guided hematoma block. Using a curvilinear transducer in transverse orientation, the fracture and associated hematoma can be identified. Then a needle can be inserted lateral to medial into the hematoma while being visualized in-plane, and local anesthetic can be injected (Figure 13.36). In the patient described above, out of the given choices, this is likely to be the safest and most effective strategy. Opiates are a poor option here not only because he is refusing, but he also has bilateral pulmonary contusions with an oxygen requirement, and opiates will depress his respiratory drive. Similarly, one of the disadvantages of the interscalene brachial plexus block is that it can cause ipsilateral phrenic nerve and therefore diaphragm paralysis—a poor choice for patients with underlying lung pathology. Finally, the serratus anterior plane block is ideal for rib fractures, but it would not be helpful for a humerus fracture.

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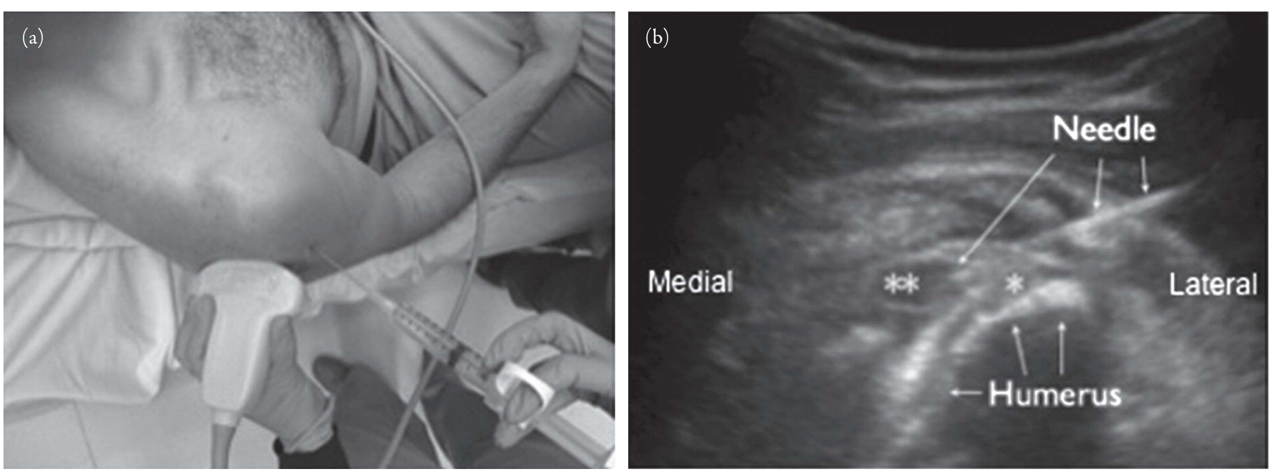

Figure 13.36 (a) Photograph of appropriate patient, curvilinear probe, and needle positioning for ultrasound-guided humeral hematoma block. (b) Ultrasound image demonstrating ultrasound-guided hematoma block of a humeral head fracture. *Hematoma. **Local infiltration of anesthetic.

Lovallo E, Mantuani D, Nagdev A. Novel use of ultrasound in the ED: ultrasound-guided hematoma block of a proximal humeral fracture. *Am J Emerg Med*. 2015 Jan 1;33(1):130–131.

Keywords/Tags: Proximal humerus fracture, hematoma block

Learning Point 36: An ultrasound-guided hematoma block can be a useful method of pain control for a patient who is too high risk for an interscalene brachial plexus block and/or is unable to safely tolerate parenteral analgesics.

37. EXPLANATION

B. Curvilinear, in-plane. Initially after placing the curvilinear transducer parallel to the inguinal ligament, the femoral vessels can be identified medially while the hyperechoic femoral head can be found laterally. Then by rotating the transducer clockwise with the probe marker now facing the umbilicus, the femoral head, neck, ilio-femoral ligament, and anterior synovial recess can be identified (Figure 13.37a). After numbing the skin, an 18-gauge spinal needle can then be inserted into the anterior synovial recess with in-plane needle visualization to aspirate synovial fluid (Figure 13.37b, Video 13.6).

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Ultrasound-guided hip arthrocentesis. In: Herring A, ed. *Highland EM Ultrasound Fueled Pain Management*. 2017. http://highlandultrasound.com/ultrasound-guided-hip-arthocentesis-and-injection/.

Keywords/Tags: Hip effusion, arthrocentesis, septic arthritis

Learning Point 37: Point of care ultrasound can assist in quickly identifying the presence of a hip effusion, and hip arthrocentesis is done with a curvilinear transducer using an in-plane approach.

38. EXPLANATION

A. Place a linear probe at the junction of the tibia and talus and perform an arthrocentesis using an out of plane approach. While the patient could certainly be having a flare of his gout, a septic ankle cannot be reliably excluded here based on history and exam alone. Synovial fluid analysis is the definitive study, and ultrasound-guided ankle arthrocentesis is a straightforward procedure that can help the clinician avoid missing septic arthritis. To perform the procedure, the linear high frequency transducer is placed in longitudinal orientation in the middle of the foot over the junction of the tibia and talus to identify the joint space (Figure 13.38). Then a needle can be inserted into this space out of plane just medial to the probe to aspirate synovial fluid.

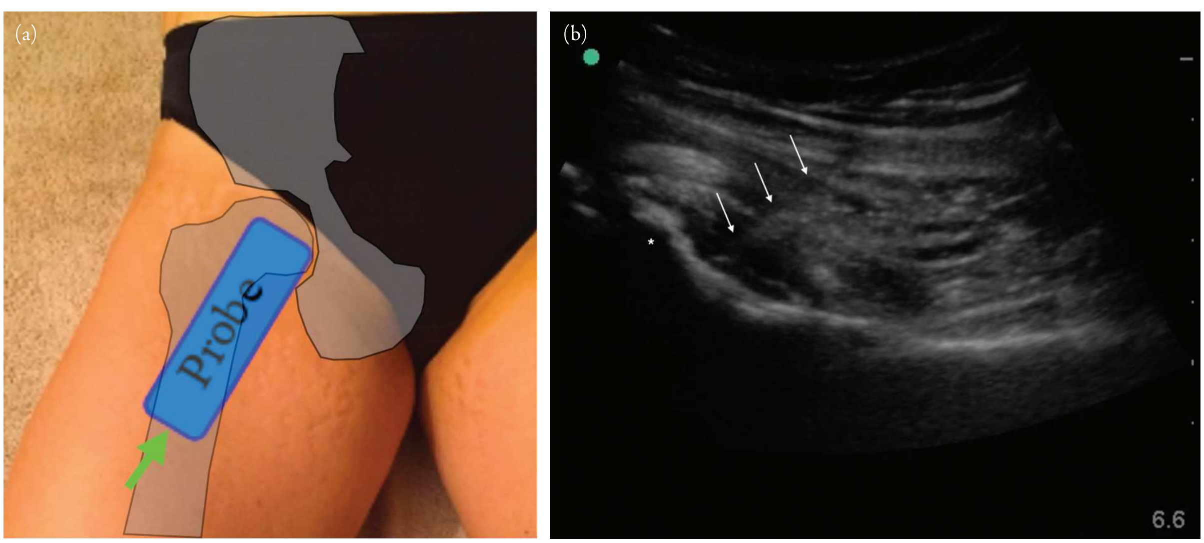

Figure 13.37 (a) **Hip arthrocentesis technique.** A curvilinear transducer is oriented towards the umbilicus to obtain a long axis view of the femoral head and acetabulum. The arthrocentesis should be performed in the in-plane approach with the needle trajectory outlined by the green arrow. (b) **Hip aspiration using in-plane approach.** → = needle; * = Femoral neck.

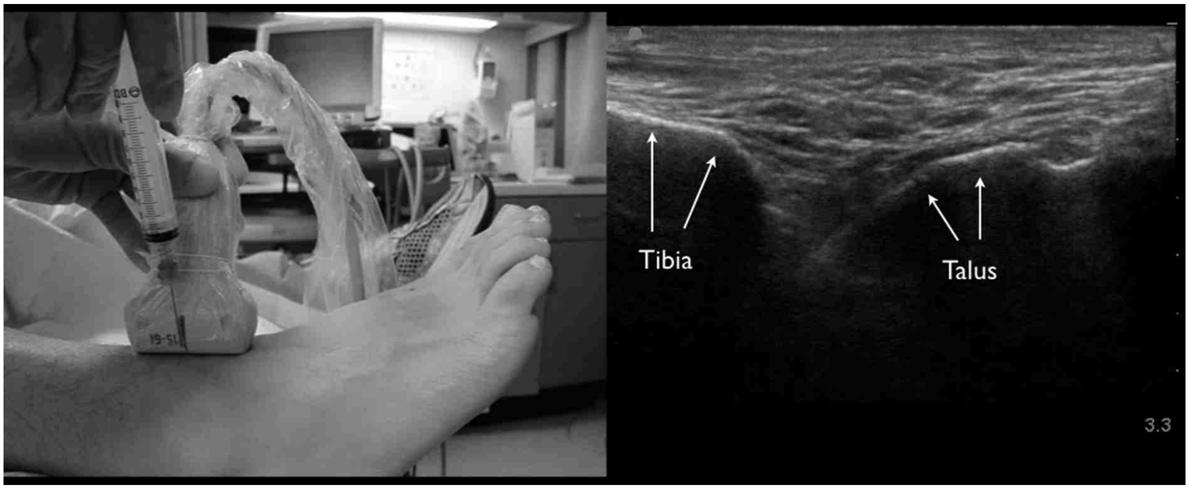

Figure 13.38 **Ultrasound guided ankle aspiration using the out of plane technique.**

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Ultrasound-guided ankle arthrocentesis. In: Herring A, *Highland EM Ultrasound Fueled Pain Management*. 2017. http://highlandultrasound.com/ankle-arthrocentesis/.

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Keywords/Tags: Ankle effusion, arthrocentesis

Learning Point 38: Ultrasound-guided ankle arthrocentesis is performed out of plane using a linear high frequency transducer after identifying the joint space between the tibia and the talus.

39. EXPLANATION

B. Below Buck's fascia. The dorsal penile nerves lie below Buck's fascia just lateral to the dorsal arteries/deep dorsal veins. The dorsal penile nerves (branches of the pudendal nerve) provide sensation to both the dorsal and ventral aspects of the penis. Using the high frequency linear transducer placed in a transverse orientation over the dorsal aspect of the penis, Buck's fascia can be readily identified (Figure 13.39). Using an in-plane approach, local anesthetic is deposited just deep to Buck's fascia to effectively target the dorsal nerves and provide effective analgesia for priapism aspiration or other procedures such as paraphimosis reduction.

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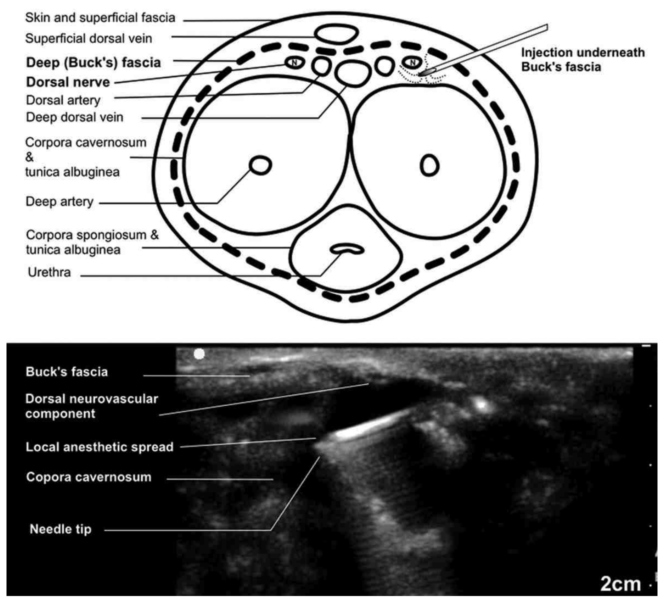

Figure 13.39 **Dorsal penile nerve block.**

Ultrasound-guided penile block. In: *Highland EM Ultrasound Fueled Pain Management*. 2017. http://highlandultrasound.com/penile-block/.

Keywords/Tags: Dorsal penile nerve block, priapism

Learning Point 39: An ultrasound-guided dorsal penile nerve block can be an effective method of periprocedural analgesia in a patient with priapism who requires bedside aspiration.

40. EXPLANATION

B. B. A = femoral nerve, B = femoral artery, C = femoral vein, D = saphenous vein. The femoral artery is a reasonable

alternative for arterial catheter placement in a critically ill patient if the radial/brachial arteries are either too clamped down or are otherwise unsuitable targets. The artery is usually located medial to the femoral nerve and just lateral to the femoral vein. In a patient with a pulse, the artery usually appears to have a thicker wall and is pulsatile. Placing color over the vessels can demonstrate pulsatile flow even more clearly. However, in a pulseless patient with CPR in progress, it is the femoral vein that pulsates with compressions.

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Keywords/Tags: Arterial line, femoral artery

Learning Point 40: The femoral artery can be identified on ultrasound as the pulsatile, thick-walled structure in between the femoral nerve (lateral) and femoral vein (medial).

41. EXPLANATION

D. A and C. The radial artery is a small superficial structure well suited to be visualized using the high-frequency linear transducer (Figure 13.40). Catheter placement in the radial artery can be performed using either an in-plane or out of plane approach. The transverse view is used for the out of plane approach and allows easier visualization of the artery and surrounding structures but is often more challenging to see the needle as only a small section of the tip is visible. The longitudinal view allows better needle visualization, but finding the exact plane of the vessel can be difficult especially for novice providers.

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Seto AH, Roberts JS, Abu-Fadel MS, et al. Real-time ultrasound guidance facilitates transradial access: RAUST (Radial Artery access with Ultrasound Trial). *JACC Cardiovasc Interv*. 2015 Feb 1;8(2):283–291.

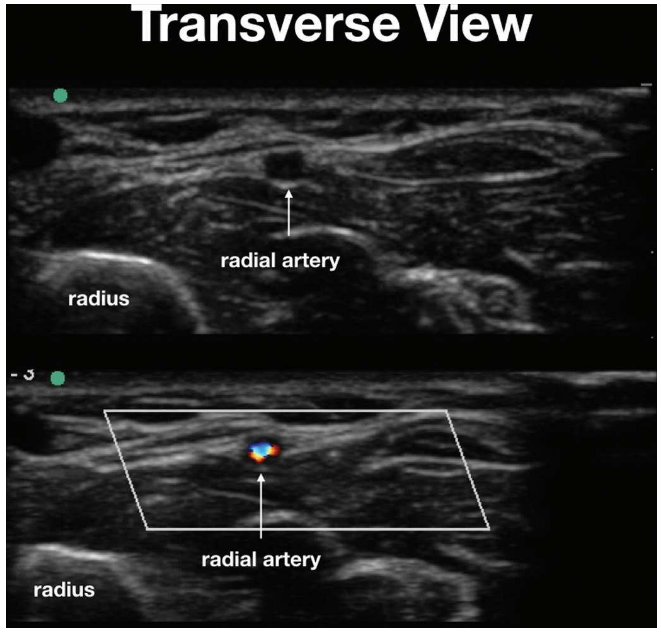

Figure 13.40 **Transverse view of the radial artery.**

Shiloh AL, Eisen LA. Ultrasound-guided arterial catheterization: a narrative review. *Intensive Care Med*. 2010 Feb 1;36(2):214–221.

Keywords/Tags: Arterial line, radial artery

Learning Point 41: To perform ultrasound-guided radial arterial catheter placement, the linear high-frequency transducer can be used in either an in-plane or out of plane approach.

42. EXPLANATION

C. Order a CT angiogram and consult vascular surgery. The clip shows that the patient does not have an abscess and, in fact, likely has a femoral artery pseudoaneurysm. While post-procedural infection is common, arterial cannulation can cause complications such as pseudoaneurysm formation, arteriovenous fistulae, expanding hematomas, and dissections that would be disastrous to cut into. Point-of-care ultrasound with color Doppler should be employed prior to I&D for suspected abscesses near the femoral vessels to evaluate for potential vascular pathology, which can present similarly.

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Keywords/Tags: Incision and drainage, abscess, pseudoaneurysm

Learning Point 42: Prior to performing an incision and drainage (I&D) for a presumed abscess near vasculature, point-of-care ultrasonography can differentiate between an uncomplicated abscess from pathology such as pseudoaneurysms that should not be incised.

43. EXPLANATION

D. Begin pacing the patient. The echo shows that the pacemaker lead has successfully been placed into the right ventricle and therefore is appropriately positioned to begin pacing the patient. On occasion a transvenous pacemaker may need to be emergently inserted into a hemodynamically unstable patient. Point-of-care ultrasonography not only allows for direct visualization of internal jugular cannulation to insert the catheter, but a quick echocardiogram can verify that the lead has been appropriately positioned in the right ventricle obviating the need for fluoroscopy. Figure 13.41 shows a pacer lead misplaced in the inferior vena cava (left) and in the right atrium (right).

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Keywords/Tags: Transvenous pacemaker, echocardiography

Learning Point 43: Point-of-care echocardiography can facilitate transvenous pacemaker placement by allowing direct visualization of the lead and whether it is successfully situated in the right ventricle.

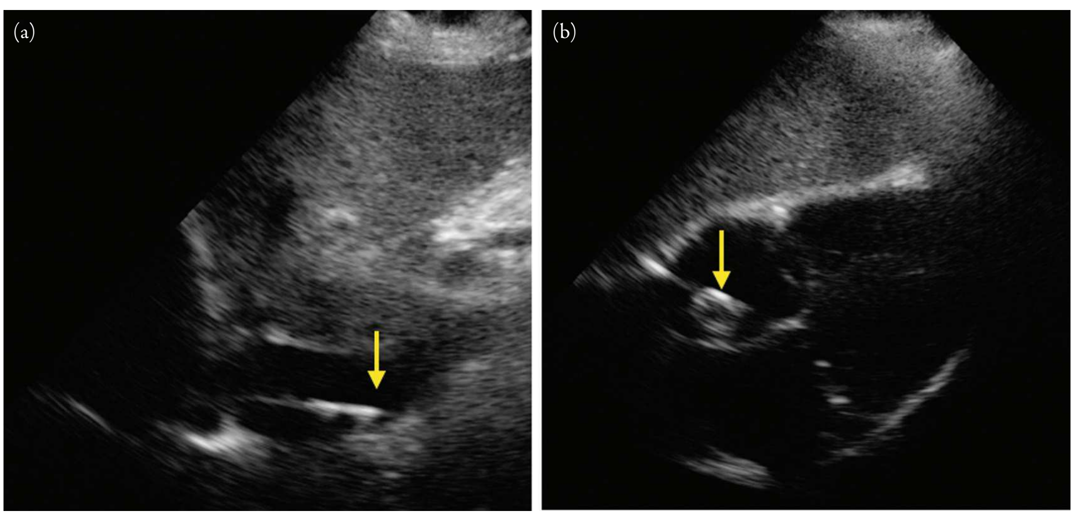

Figure 13.41 **Transvenous pacer lead misplaced in the inferior vena cava (a) and the right atrium (b).**

14.

AIRWAY AND ENT

Shadi Lahham, Tushank Chadha, Michelle Bui, Sophia Spann, and Abdulatif Gari

QUESTIONS

1. In a patient undergoing anterior neck ultrasound for evaluation of an anterior neck mass, what sonographic finding suggests a benign thyroid nodule as opposed to malignancy?

A. Surrounding hypoechoic halo
B. Blood flow through the mass as seen on ultrasound Doppler
C. Scant nodules throughout thyroid
D. Poorly defined edges surrounding the nodule

2. Grave's disease on thyroid ultrasound is characterized by an enlarged, __________ thyroid that is ______ and __________.

A. Hypoechoic, homogeneous, hypovascular
B. Hypoechoic, heterogeneous, hypervascular
C. Hyperechoic, heterogeneous, hypervascular
D. Hyperechoic, heterogeneous, hypovascular

3. A 55-year-old male with a history of hypertension, diabetes, chronic obstructive pulmonary disease, and obesity presents with acute shortness of breath. His vital signs are heart rate 110, respiratory rate 38, blood pressure 105/62, and SpO_2 83% on room air. You are preparing for emergent intubation. What sonographic findings can help you predict if this may be a difficult laryngoscopy?

A. Geniohyoid thickness
B. Distance between skin and hyoid bone
C. Thyromental distance
D. Vocal cord function

4. What sonographic findings would be most relevant in diagnosing and differentiating between mild, moderate, and severe bulb intimal carotid artery stenosis?

A. The end diastolic velocity and internal carotid artery (ICA) to common carotid artery (CCA) ratio
B. Intima-media thickness and internal common artery peak systolic velocity (PSV)
C. The PSV and ICA to CCA ratio
D. The diameter of the ICA in relation to the size of the internal jugular vein

5. A 32-year-old female presents with neck swelling for the past 4 weeks. For a patient with an anterior neck mass, how might one differentiate parathyroid gland tissue from the thyroid gland on ultrasound?

A. The parathyroid gland appears homogeneously hypoechoic when compared to overly echogenic thyroid gland.
B. The parathyroid gland is heterogeneously hypoechoic when compared to the hyperechoic thyroid gland.
C. The parathyroid gland has increased color flow uptake relative to the thyroid gland.
D. The parathyroid gland has decreased color flow uptake relative to the thyroid gland.

6. In regards to Doppler tracing, what 2 sonographic features can be used to distinguish the external carotid artery (ECA) from the ICA?

A. The ICA demonstrates high peripheral resistance flow whereas the ECA demonstrates low peripheral resistance flow.
B. The ECA is larger in diameter than the ICA.
C. The ECA is compressible while the ICA is not compressible.
D. The ICA demonstrates low peripheral resistance flow whereas the ECA demonstrates high peripheral resistance flow.

7. When using an ultrasound to place a central line into the subclavian vein, attenuation from the ___________

can lead to ___________ on the ultrasound image, making visualization of the subclavian vein difficult.

A. Sternocleidomastoid muscle, acoustic shadowing
B. Clavicle, acoustic shadowing
C. Clavicle, a reverberation artifact
D. Sternocleidomastoid muscle, impedance

8. When visualizing lymph nodes (LNs) using an ultrasound, they are found in the ___________. Benign nodes are oval in shape and when visualized on a short axis view they measure 5 to 6 mm with a/an _____________.

A. Subcapsular sinus, heterogeneous hypoechoic hilum
B. Parenchyma, heterogeneous hyperechoic hilum
C. Parenchyma, homogenous hyperechoic hilum
D. Subcapsular sinus, anechoic hilum

9. In a 65-year-old male presenting with a painless mass to the parotid region, the ultrasound finding of heterotopic parotid tissue located within parotid LNs (see Figure 14.1) is indicative of which pathology?

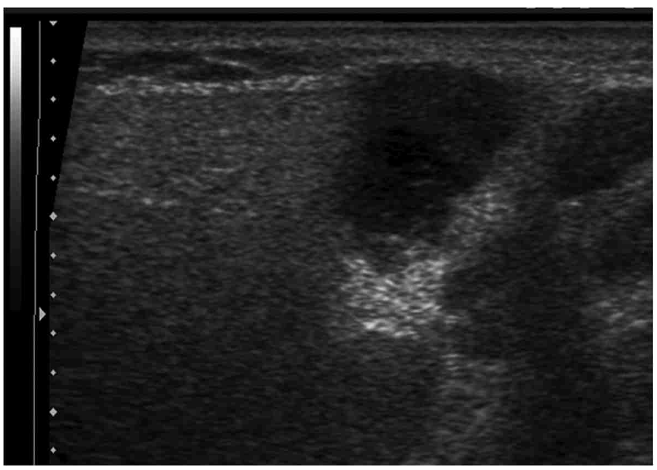

Figure 14.1

A. Warthin's tumor
B. Pleomorphic adenoma
C. Oncocytoma
D. Hemangioma

10. In a patient presenting with sore throat or unilateral throat swelling, intraoral ultrasound can be used to differentiate between a peritonsillar abscess (PTA) and tonsillitis. What findings are indicative of each?

A. Tonsillitis is diagnosed by findings of enlarged tonsils that have a heterogeneous or cystic appearance, while a PTA is demonstrated by enlarged tonsils that have a homogenous or striated appearance.
B. Tonsillitis is diagnosed by findings of enlarged tonsils that have a homogenous or striated appearance, while a PTA is demonstrated by enlarged tonsils that have a heterogeneous or cystic appearance.
C. Both tonsillitis and PTA distort the tonsil medially and caudally and demonstrate similar echogenic patterns on intraoral ultrasound, making needle aspiration required for correct diagnosis.
D. Both tonsillitis and PTA are demonstrated by heterogeneous or cystic appearances on intraoral ultrasound. PTC is indicated by a potentially inseparable distortion on the tonsil with mass affect and can be differentiated by identifying this trait.

11. A 25-year-old male presents to your emergency department with left facial swelling he states began 2 days ago. He reports chronic swelling to the location for multiple months, which has become worse after squeezing the area 2 days ago. His vital signs are within normal limits and he denies any fevers, chills, neck stiffness, or vision changes with his symptoms. On physical exam you find left periorbital and malar erythema, edema, and evidence of an overlying pustule with scant serous exudate. There is tenderness to palpation. A CT scan of this patient (Figure 14.2a) and subsequent point-of-care ultrasound was obtained (Figure 14.2b). Based on the patient presentation and the imaging modalities, which of the following statements is true?

A. There is no evidence of an abscess in Figure 14.2a, but the green arrow in Figure 14.2b depicts a drainable abscess.
B. There is no evidence of an abscess in any of the images, and based on the patient's report he should be treated only for cellulitis.
C. The green arrow in Figure 14.2b is a hyperechoic area, which demonstrates a hard mass that does not necessitate drainage.
D. Given that a CT scan is the highest quality of imaging and there is no evidence of an abscess present in Figure 14.2a, the patient does not have an abscess and should be only treated for cellulitis.

12. A 38-year-old male presents with a painless anterior neck mass that he has noticed for 3 weeks. What sonographic feature is most highly associated with thyroid malignancy?

A. Punctate echogenic foci with posterior shadowing
B. Lymph nodes with decreased color Doppler flow
C. Nodule with no edge refraction shadow
D. Punctate echogenic foci without posterior shadowing

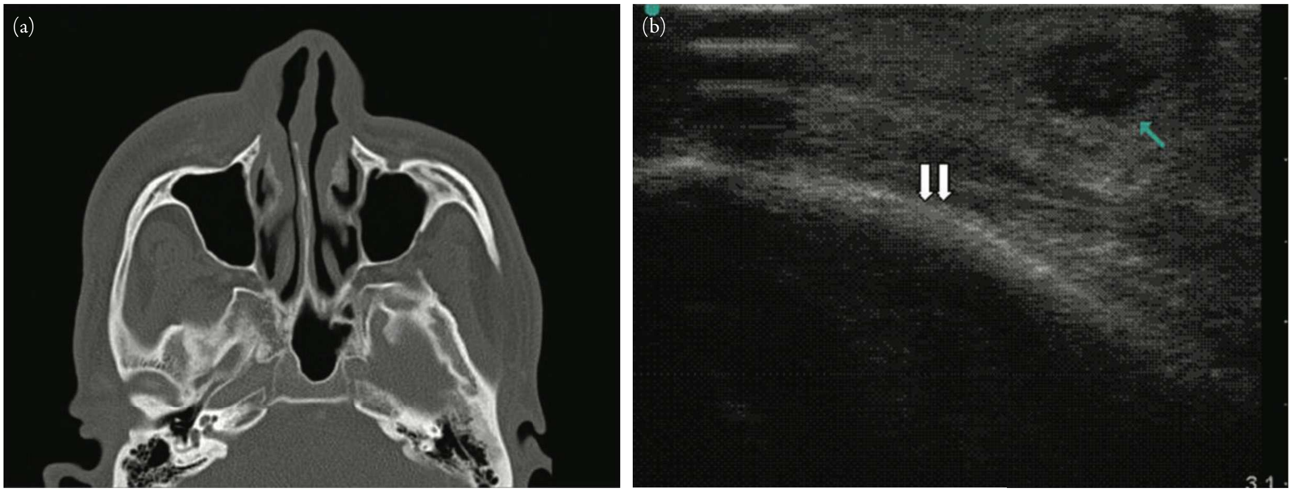

Figure 14.2

13. What ultrasonographic finding defines the Carotid intima-media thickness (IMT)?

A. The distance between the 2 echogenic lines representing the lumen-intima and the media-adventitia interface
B. The diameter of the lumen of the carotid artery from outer wall to outer wall
C. The distance between the carotid bulb and ECA
D. The distance from the internal jugular vein outer layer to the outer layer of the carotid artery at the bifurcation of the carotid artery

14. A 78-year-old male patient was discharged 2 days ago to a skilled nursing facility. You look at his recent hospitalization and notice that he was admitted 6 days ago for septic shock from pneumonia requiring a central line and vasopressors. On presentation today the patient has a heart rate of 110, respiratory rate of 29, blood pressure of 88/45, and SpO_2 of 88% on room air. The urinalysis reveals large leukocytes and positive nitrites. You start intravenous (IV) antibiotics, and 30cc/kg of Normal saline are given with minimal improvement of blood pressure. You decide to place a central venous catheter to start vasopressors. You are about to perform an ultrasound-guided central line of the right internal jugular vein and see the image in Figure 14.3 and Video 14.1. Which of the following is *not* associated with the complication seen?

A. Larger circumference of the catheter
B. Right-sided central venous catheter insertion
C. Multiple venipuncture attempts
D. Positioning of central venous catheter in the proximal superior vena cava

Figure 14.3

15. Which feature seen on ultrasound is *not* indicative of a thyroglossal duct cyst in children?

A. Irregular wall or inner contour of the cyst is not well defined
B. Presence of internal septae
C. Evidence of posterior acoustic shadowing
D. Solid compartments

16. In Sjögren's syndrome, the salivary glands are typically __________ and inhomogeneous, and the salivary glands may ___________.

A. Hyperechoic, atrophy
B. Hypoechoic, atrophy
C. Hypoechoic, enlarge
D. Hyperechoic, enlarge

17. What sonographic findings indicate the presence of a carotid artery plaque?

A. Leaflet within the carotid artery that has hypoechoic structures attached proximally
B. Hyperechoic debris traveling within the lumen of the carotid artery
C. Carotid artery focal wall thickening greater than 50% of the surrounding IMT or greater than 0.5 mm
D. Carotid artery wall thickness less than 1.5 mm measured from the intima-lumen interface to the media-adventitia interface

18. What sonographic findings are consistent with a nasal bone fracture?

A. Cortical irregularity of nasal bone structures
B. Interruption in continuity of bony structures within the nose
C. Diffuse soft tissue swelling of the nasal lateral walls
D. All of the above

19. A 28-year-old male presents to the emergency department with sore throat, left neck swelling, trismus, and fever. On examination of the patient's throat, you see deviation of the uvula toward the right and severe swelling of the left tonsillar area. You perform an ultrasound of the neck and visualize the left internal jugular vein as seen in Figure 14.4. What is the next best step in management?

A. Oral antibiotic prescription and discharge with follow-up with ENT clinic.
B. Obtain CT scan of the head.
C. Consult interventional radiology for urgent thrombectomy.
D. Start IV antibiotics and anticoagulation then admit for inpatient management

20. A 59-year-old male presents with septic shock from an intra-abdominal infection. You decide to place an internal jugular central venous line. After threading the guidewire and before dilation, you place the probe in long axis on the right internal jugular vein and see the image in Figure 14.5. What is the next best step in management?

Figure 14.4

A. Call interventional radiology for foreign body removal.
B. Attempt central line on left internal jugular vein.
C. Continue with central line placement of the right internal jugular vein.
D. Start anticoagulation.

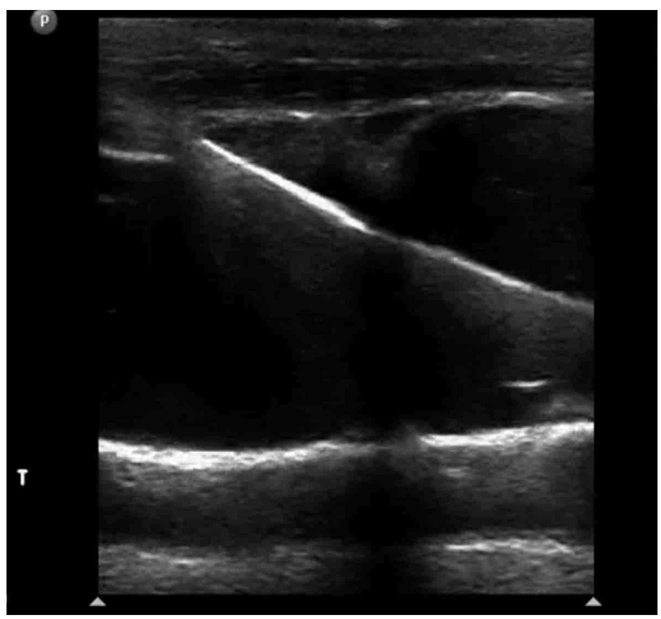

Figure 14.5

21 In a patient with concern for unexplained hypotension, jugular venous pressure (JVP) can be estimated using point-of-care ultrasound. Which of the following statements is true?

A. An ultrasound-JVP of 6 cm is considered normal.
B. Physical examination has similar sensitivity and specificity to ultrasound for JVP measurements.
C. Patient must be placed in supine position for measurements to be considered accurate.
D. Internal jugular central vein measurements correspond well to inferior vena cava measurements for patients with hypotension.

ANSWERS

1. EXPLANATION

A. Surrounding hypoechoic halo. A lesion within the thyroid gland is defined as a structure that is radiologically distinct from the thyroid parenchyma. On point-of-care ultrasound examination of the thyroid, malignancy is suspected from findings of ill-defined margins or irregular margins, blood flow visualized through a mass, and multiple nodules within the thyroid. The hypoechoic halo surrounding a thyroid nodule is produced by a pseudocapsule of fibrous connective tissue, compressed thyroid parenchyma, and chronic inflammatory infiltrates (see Figure 14.6a). A thyroid with an absent halo or incomplete halo is more suggestive of malignancy (see Figure 14.6b). These patients should be referred for formal ultrasonography and possible fine needle aspiration or biopsy.

Learning Points: Thyroid malignancy should be suspected from findings of ill-defined margins or irregular margins, blood flow visualized through a mass, and multiple nodules within the thyroid.

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Keywords/Tags: Thyroid ultrasound, thyroid nodule

2. EXPLANATION

C. Hyperechoic, heterogeneous, hypervascular. Grave's disease is an autoimmune thyroid disease of an overactive thyroid gland. On ultrasound examination, Grave's disease can be identified by visualization of overgrowth of the thyroid tissue, which will present as hyperechoic. The echotexture of the thyroid is heterogeneous on exam, diffusely overgrown and hypervascular (see Figure 14.7a). The sonographer may also visualize a "thyroid inferno" pattern on color Doppler (see Figure 14.7b). Note that other conditions including thyroiditis and Hashimoto's disease can be indistinguishable on ultrasound alone and require both clinical and laboratory correlation.

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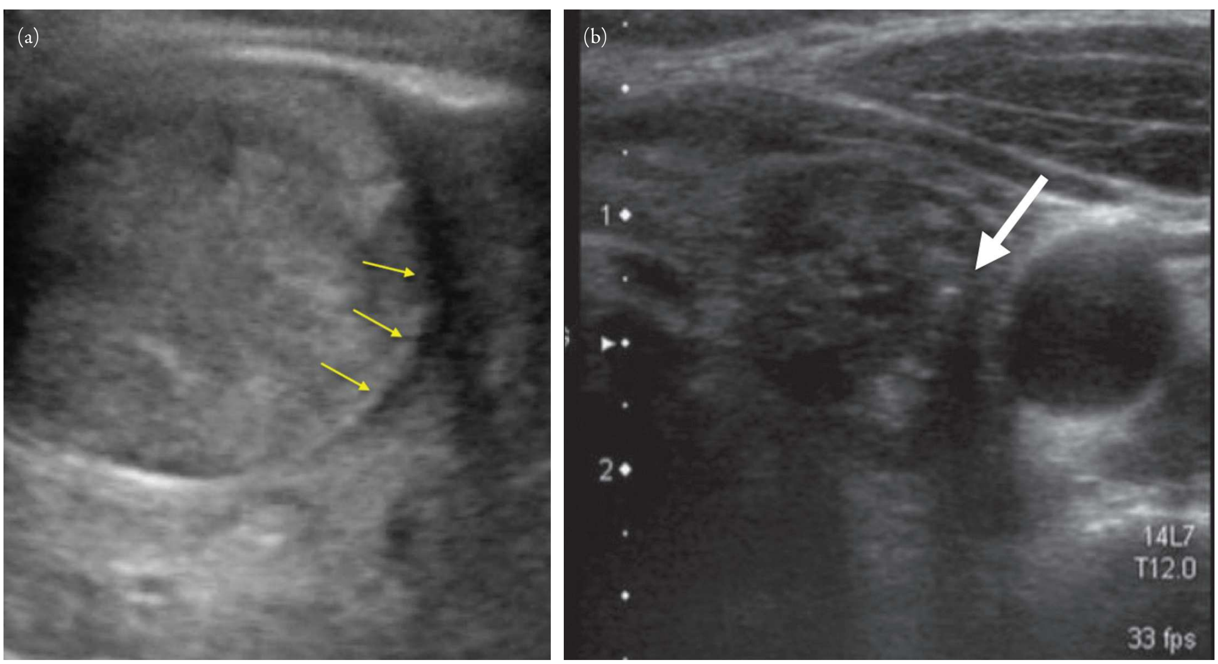

Figure 14.6 (a) **Solid nodule showing a discrete hypoechoic rim (arrows) along its entire circumference is highly suggestive of benignity.** Adapted from Figure 7B of Hedge A, Chong FH. Thyroid nodules: risk stratification for malignancy with ultrasound and guided biopsy. *Cancer Imag.* 2011;11(1):209–223. (b) **A malignant nodule shows irregular spiculated outlines, which are solid and hypoechoic with microcalcifications and shadowing (arrow).** Adapted from Figure 8B of Hedge A, Chong FH. Thyroid nodules: risk stratification for malignancy with ultrasound and guided biopsy. *Cancer Imag.* 2011;11(1):209–223.

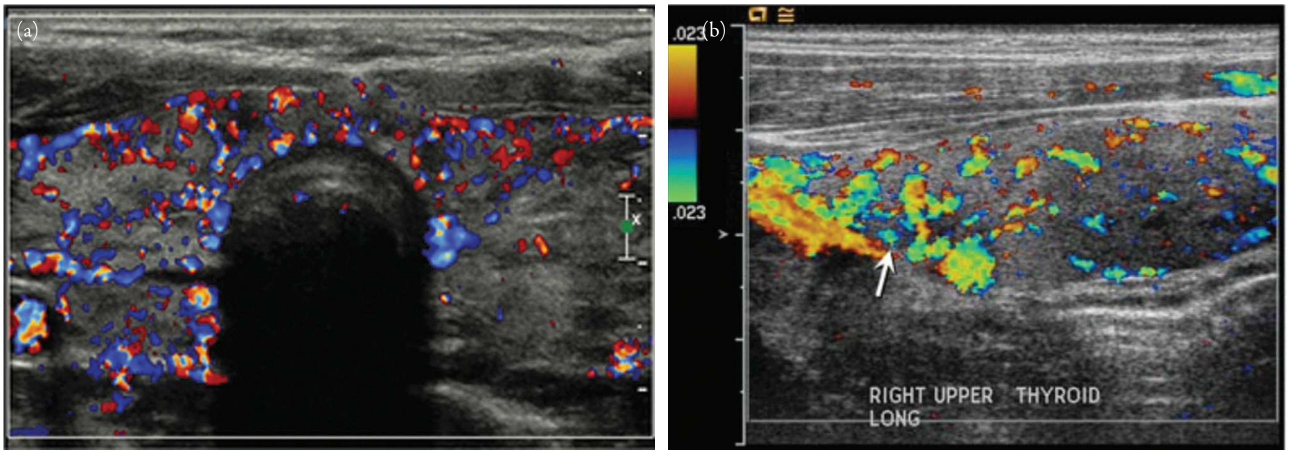

Figure 14.7 (a) **This transverse image of the thyroid gland (arrow) shows diffuse enlargement and hypervascularity in this patient with Hashimoto thyroiditis.** From Figure 133.3 of Scoutt LM, Hamper UM, Angtuaco L, eds. *Ultrasound.* Oxford, UK: Oxford University Press; 2017. (b) **Longitudinal image of the right thyroid gland (arrow).** This image shows a "thyroid inferno" pattern of hypervascularity on color Doppler in a patient with Grave's disease. From Figure 2C of McIver B, Fatourechi MM, Hay ID, Fatourechi V. Grave's disease after unilateral Riedel's thyroiditis. *J Clin Endocrinol Metab.* 2010; 95(6):2525–2526.

Scoutt LM, Hamper UM, Angtuaco L, eds. *Ultrasound*. New York, NY: Oxford University Press; 2017.

Keywords/Tags: Graves' disease, thyroid ultrasound

3. EXPLANATION

B. Distance between skin and hyoid bone. On an ultrasound assessment of the anterior neck soft tissue, an increased sonographic thickness of the anterior neck soft tissue of the hyoid bone and thyrohyoid membrane predicted difficult intubation (see Figure 14.8a). Adhikari et al. (2011) found that the average distance between skin to hyoid bone for difficult versus easy laryngoscopy was 1.69 cm versus 1.27 cm. They also found the average distance between skin to thyrohyoid membrane for difficult versus easy laryngoscopy was 3.47 cm versus 2.37 cm (see Figure 14.8b). Geniohyoid (tongue) thickness was not associated with difficult laryngoscopy in that study, so choice A is incorrect. Thyromental distance is a physical exam finding from the distance of the thyroid cartilage to the mental prominence, so choice C is incorrect. Assessment of vocal cord function can be helpful to assess for vocal cord paralysis or dysfunction. However, it does not predict if laryngoscopy will be difficult, so choice D is incorrect.

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Keywords/Tags: Anterior neck ultrasound, airway ultrasound, laryngoscopy, difficult airway

4. EXPLANATION

C. The PSV and ICA to CCA ratio. Normal ICA PSV is less than 125 cm/second and end diastolic velocity is less than 40 cm/second with no plaque or intimal thickening visible sonographically (see Figure 14.9). Additionally, the ICA/CCA PSV ratio on a normal exam will be less than 2.0. With mild (<50%), moderate (50%–69%), and severe (>70%) ICA stenosis, sonographic findings of the PSV and ICA/CCA are as shown in Table 14.1.

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Rohren EM, Kliewer MA, Carroll BA, Hertzberg BS. A spectrum of Doppler waveforms in the carotid and vertebral arteries. *AJR Am J Roentgenol*. 2003;181(6):1695–1704.

Keywords/Tags: Internal carotid artery stenosis, peak systolic velocity

5. EXPLANATION

A. The parathyroid gland appears homogeneously hypoechoic when compared to overly echogenic thyroid gland. When performing a thyroid ultrasound exam, the patient should be in supine position with hyperextended

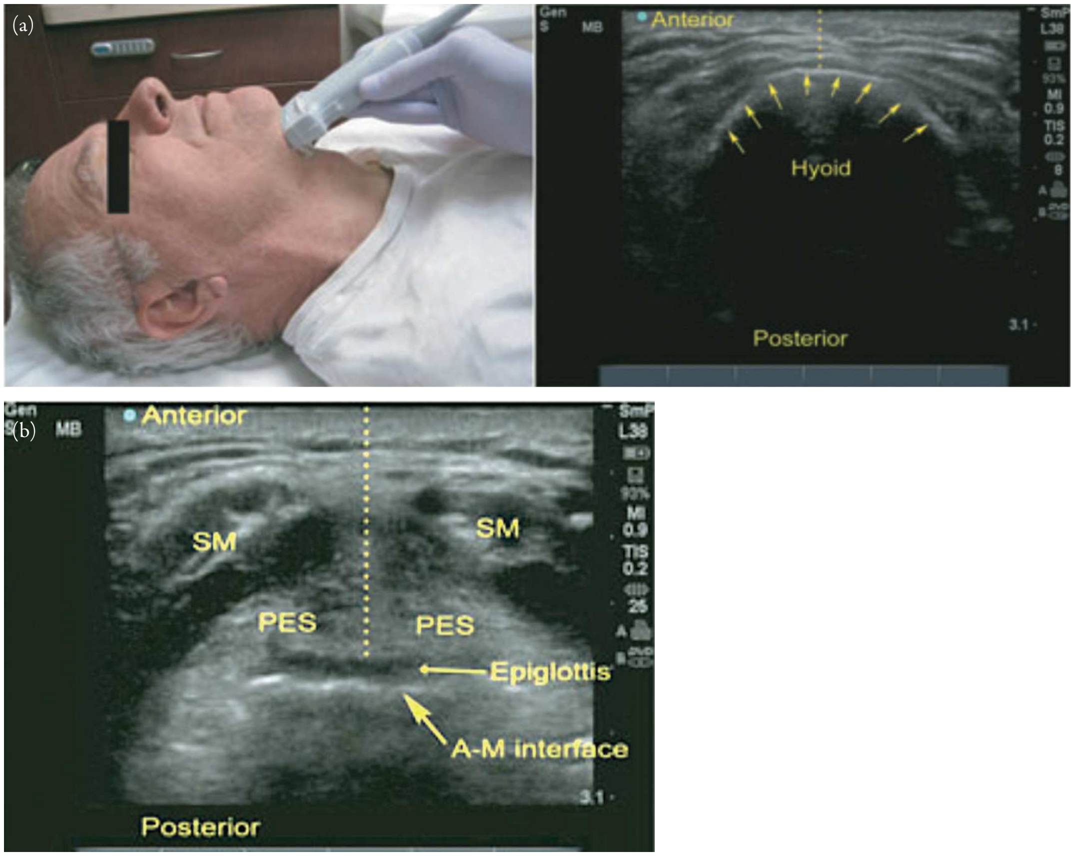

Figure 14.8 (a) **Measurement of distance between skin and hyoid bone (dotted lines).** Adapted from Figure 2B of Adhikari S, Zeger W, Schmier C, et al. Pilot study to determine the utility of point-of-care ultrasound in the assessment of difficult laryngoscopy. *Acad Emerg Med*. 2011;18(7):754–758. doi:10.1111/j.1553-2712.2011.01099.x. (b) **Measurement at the level of thyrohyoid membrane.** Measurement obtained from skin to epiglottis midway between the hyoid bone and thyroid cartilage. SM = strap muscles; PES = preepiglottic space; A-M interface = air-mucosa interface. Adapted from Figure 2C of Adhikari S, Zeger W, Schmier C, et al. Pilot study to determine the utility of point-of-care ultrasound in the assessment of difficult laryngoscopy. *Acad Emerg Med*. 2011;18(7):754–758. doi:10.1111/j.1553-2712.2011.01099.x.

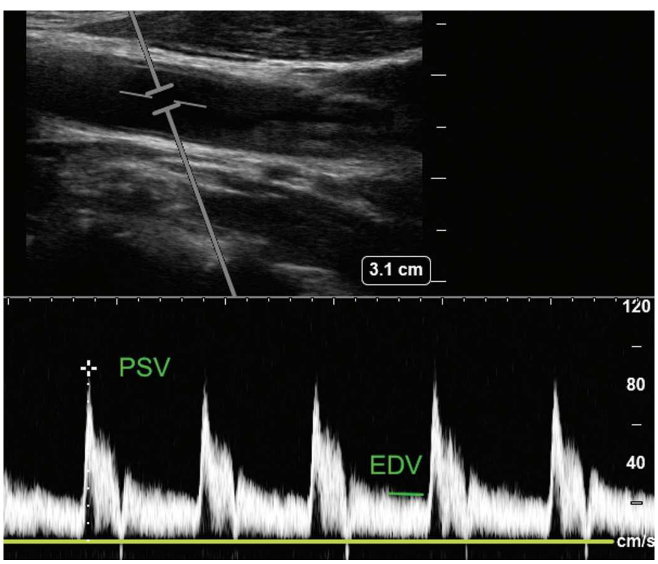

Figure 14.9 Ultrasound image of a patient with normal internal carotid artery with peak systolic velocity (PSV) less than 125 cm/second and end diastolic velocity (EDV) less than 40 cm/s.

Table 14.1 ULTRASOUND CRITERIA FOR DIAGNOSIS OF ICA STENOSIS

- Mild ICA stenosis
  - ICA PSV <125 cm/sec and plaque or intimal thickening is visible sonographically
  - ICA/CCA PSV ratio <2.0
  - ICA EDV <40 cm/sec
- Moderate ICA stenosis
  - ICA PSV is 125-230 cm/sec and plaque is visible sonographically
  - ICA/CCA PSV ratio of 2.0-4.0
  - ICA EDV of 40-100 cm/sec
- Severe ICA stenosis
  - ICA PSV >230 cm/sec and visible plaque and luminal narrowing are seen at gray-scale and color Doppler
  - ICA/CCA PSV ratio >4
  - ICA EDV >100 cm/sec

ICA = Internal Carotid Artery; PSV = peak systolic velocity; CCA = common carotid artery; EDV = end diastolic velocity.

Adapted from Table 3 of: Grant EG, Benson CB, Moneta GL, et al. Carotid artery stenosis: gray-scale and Doppler US diagnosis--Society of Radiologists in Ultrasound Consensus Conference. In: Vol 229. 2003:340-346.

neck, and a high-frequency linear-array transducer should be utilized to obtain both transverse and longitudinal planes of visualization (see Figure 14.10a). The examination should include the entire neck, looking for abnormal lymph nodes (LNs), enlarged parathyroid glands, and abnormal masses. The antero-lateral face of the thyroid is bordered by the sternohyoid and sternothyroid muscles; these have a fibrillary structure and appear hyperechoic to the overly echogenic thyroid gland (see Figure 14.10b). The parathyroid glands are located at the posterior face of the thyroid lobes in the extra capsular position. The 4 glands are normally small and are usually not visualized well on ultrasound (see Figure 14.10c). Enlarged parathyroid glands or those that are easily seen on exam should be noted by the sonographer and are highly suspicious for abnormal tissue.

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Keywords/Tags: Parathyroid ultrasound, thyroid ultrasound

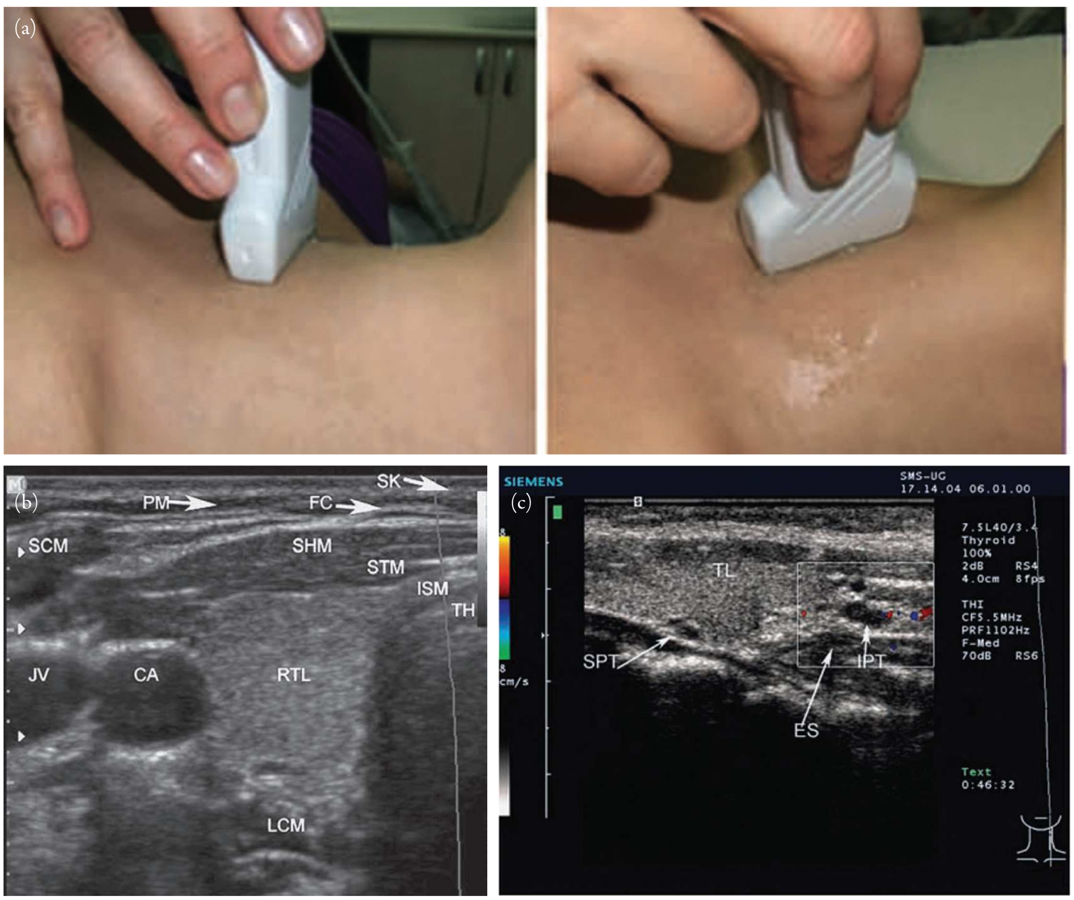

Figure 14.10 (a) **Scanning technique for examination of the thyroid.** (A) Transverse view of the thyroid. (B) Longitudinal section of the right thyroid. Adapted from Figures 1a and 1b of Ghervan C. Thyroid and parathyroid ultrasound. *Med Ultrason*. 2011;13(1):80–84. (b) **Transverse view of the right thyroid.** SK = skin, PM = platisma muscle, FC = fascia cervicalis, SHM sternohyoid muscle, STM = sternothyroid muscle, SCM = sternocleidomastoid muscle, ISM = isthmus, TH = trachea, RTL = right thyroid lobe, JV = jugular vein, CA = carotid artery, ESP = esophagus, LCM = longus colli muscle. Adapted from Figure 2 of Ghervan C. Thyroid and parathyroid ultrasound. *Med Ultrason*. 2011;13(1):80–84. (c) *Longitudinal view of normal parathyroid glands.* Color Doppler is used to help differentiate glands from vasculature structures. TL = thyroid lobe, SPT = superior parathyroid gland, IPT = inferior parathyroid gland, ES = esophagus. Adapted from Figure 9 of Ghervan C. Thyroid and parathyroid ultrasound. *Med Ultrason*. 2011;13(1):80–84.

6. EXPLANATION

D. The ICA demonstrates low peripheral resistance flow whereas the ECA demonstrates high peripheral resistance flow. The anatomical difference between the ECA and the ICA using ultrasound can be challenging to distinguish, depending on the approach we use to scan. In healthy individuals, measuring Doppler flow velocity can distinguish the difference. The ICA will show low resistance waveform with forward flow even during diastole (see Figure 14.9). The ECA will have high resistance waveform with retrograde flow during diastole (see Figure 14.11). In patients with atherosclerosis, it may be more difficult to rely on the flow velocity due to changes in lumen size. Using Valsalva may help distinguish these vessels.

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Keywords/Tags: External carotid artery, internal carotid artery

7. EXPLANATION

A. Clavicle, acoustic shadowing. The subclavian vein, subclavian artery, and the clavicle are in close anatomical proximity, which makes using the proper ultrasound techniques important when inserting a central line. As an ultrasound beam passes through a medium, energy is absorbed, scattered, or reflected. Attenuation is when ultrasound waves are absorbed by a dense structure. In this case, the clavicle is a dense bony structure that would attenuate all or most of the ultrasound waves leading to shadowing. Impedance is a physical property of a specific tissue and is determined by the density of the tissue as well as the speed of sound through that tissue. If there is a significant difference of impedance between 2 tissue interfaces, this can result in reflection of sound waves. If part of an ultrasound beam changes direction in a less orderly fashion, the event is usually described as "scatter." Using a small footprint ultrasound probe beneath the middle third of the clavicle in short axis first then in long axis can make it easier to visualize these structures without impedance or attenuation (see Figure 14.12).

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Keywords/Tags: Subclavian central line, central venous access, impedance, attenuation

8. EXPLANATION

C. Parenchyma, homogenous hyperechoic hilum. To visualize LNs using ultrasound in short axis and long axis

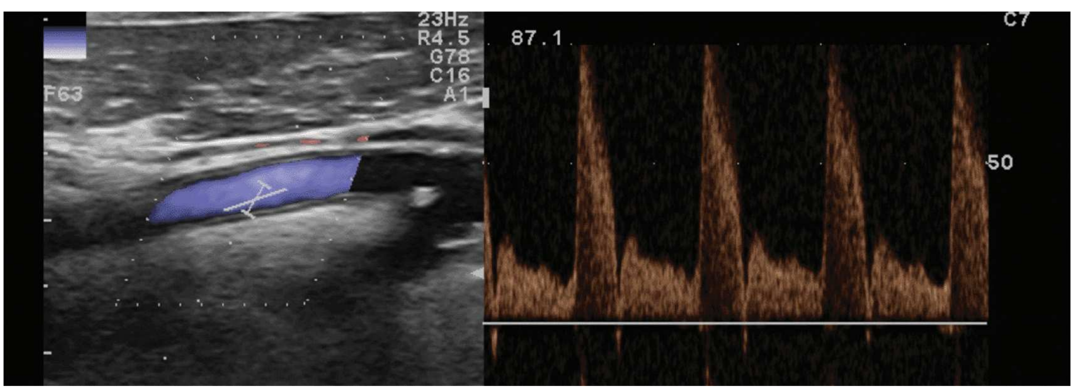

Figure 14.11 **External carotid artery waveform.** Doppler sonogram shows external carotid artery that supplies high-resistance vascular beds of osseous and muscular structures of head and neck; thus, waveform is characterized by sharp rise in flow velocity during systole, rapid decline toward baseline, and diminished diastolic flow. Adapted from Figure 68.7 of Sprynger M, et al. Vascular echo imaging. In: Lancellotti P, Zamorano JL, Habib G, Badano L, eds. *The EACVI Textbook of Echocardiography*. 2nd ed. Oxford, UK: Oxford University Press; 2016.

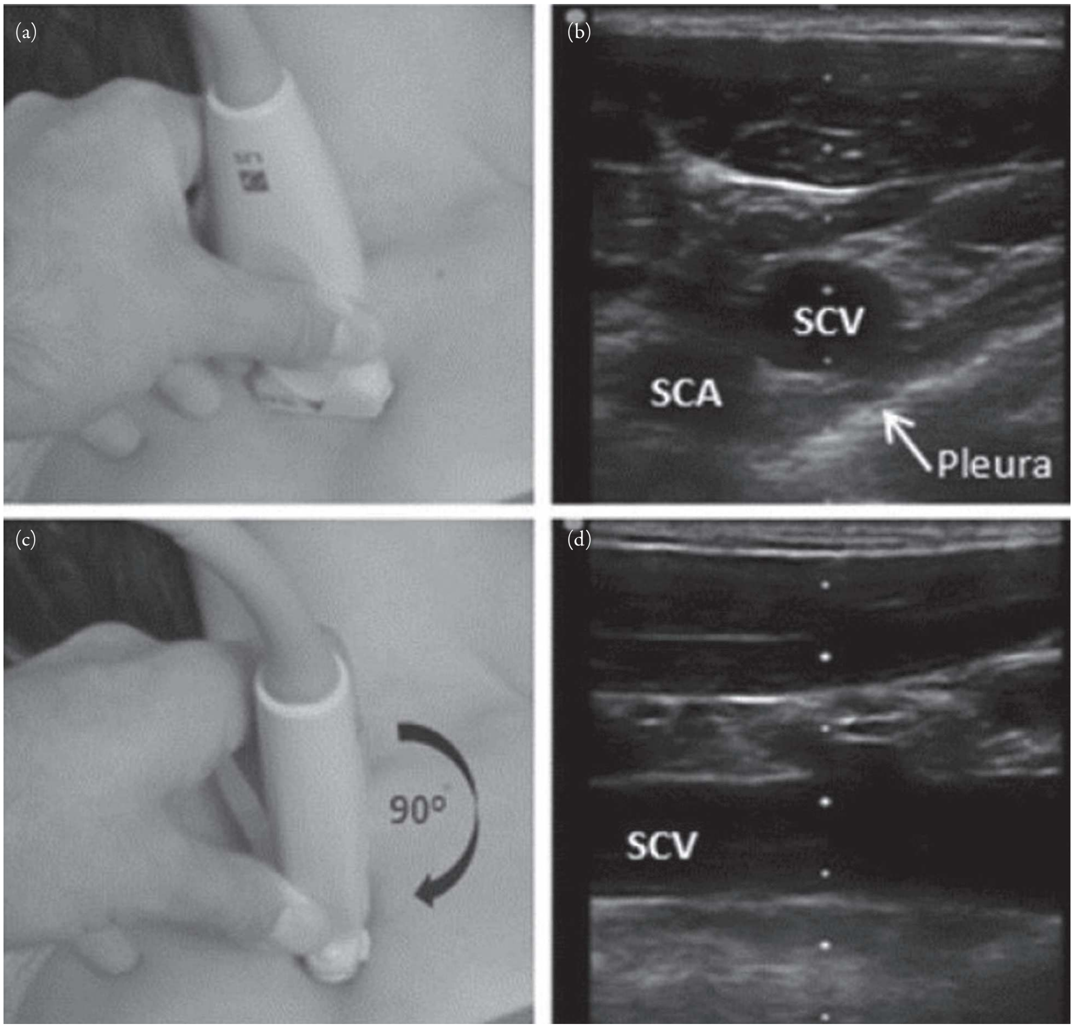

Figure 14.12 (a) The linear transducer is placed perpendicularly and inferior to clavicle. (b) Identified anatomical structures include the transverse (short axis) view of subclavian vein (SCV), subclavian artery (SCA) and pleura. (c) With SCV centrally positioned, the transducer is rotated 90° clockwise until (D) longitudinal view of subclavian vein is obtained. Adapted from Figure 2 of Rezayat T, Stowell JR, Kendall JL, et al. Ultrasound-guided cannulation: time to bring subclavian central lines back. *West J Emerg Med*. 2016;17(2):216–221.

view, it is crucial to correctly identify the LN. The shape, size, echogenicity, and homogeneity can help determine benign versus pathologic processes. Homogenous structures with hyperechoic hilum are indicative of LNs (see Figure 14.13a). Structures with an anechoic hilum tend to be cystic or fluid filled (see Figure 14.13b). Structures with heterogeneous fluid are more likely to represent an abscess. If a LN is found, there are some ultrasound characteristics than can help differentiate between benign versus malignant LNs (see Table 14.2).

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Keywords/Tags: Lymph node ultrasound

9. EXPLANATION

A. Warthin's tumor. The ultrasound image shows the typical appearance of a Warthin's tumor (arrows). The lesion is oval, well defined, hypoechoic, and inhomogeneous with multiple irregular anechoic areas and posterior acoustic enhancement. Warthin's tumor (adenolymphoma) or papillary cystadenoma lymphomatosum is the second most common benign tumor in the parotid gland. It originates from the entrapment of heterotopic salivary gland ductal

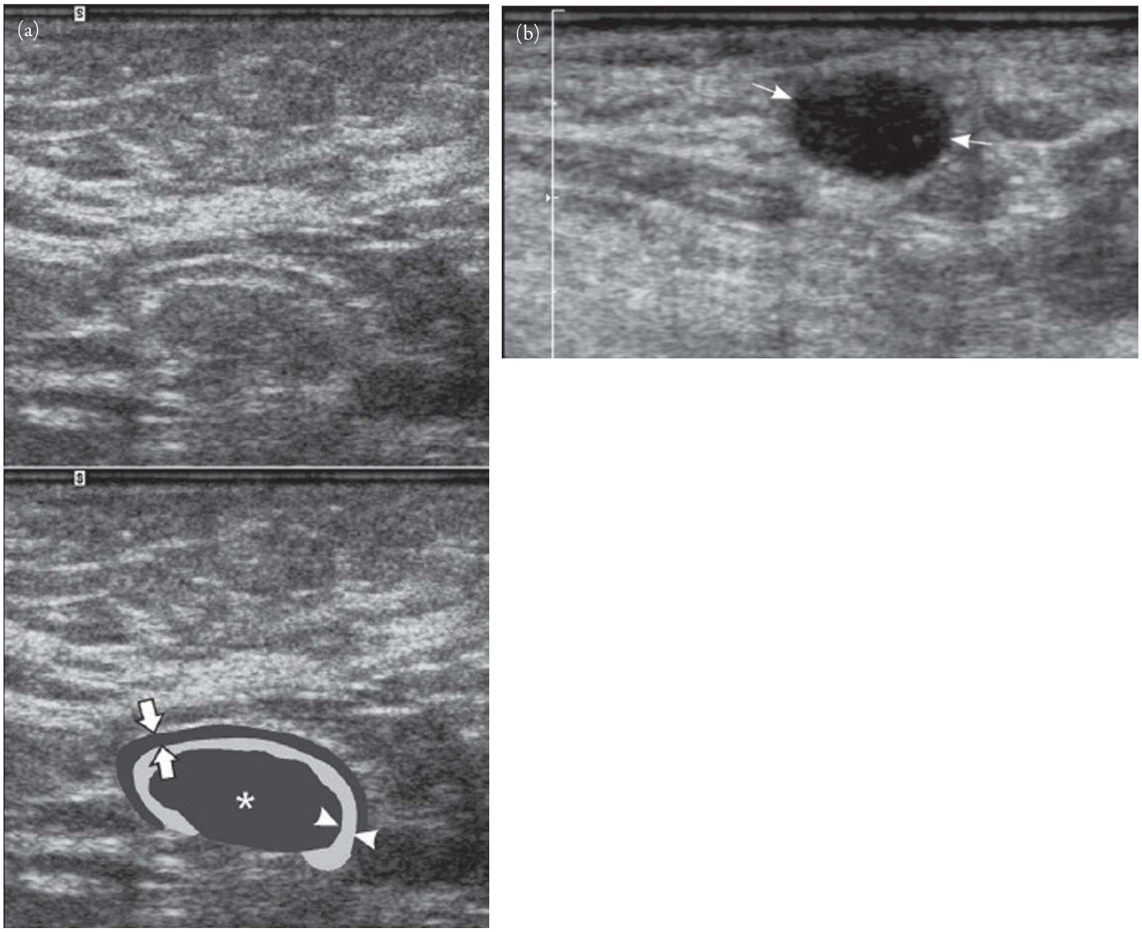

Figure 14.13 (a) **Illustration of a lymph node.** The thin parenchymal layer is visible as a hypoechoic layer (arrows) and is followed by another, internal hyperechoic layer, which represents translocated connective tissue of the hilum along with blood and lymphatic vessels (arrowheads). Adapted from Figure 1 of Bialek, EJ, Jakuboski W. Mistakes in ultrasound diagnosis of superficial lymph nodes. *J Ultrason*. 2017;17:59–65.
(b) **An oval, well-delineated focal lesion (arrows) with acoustic enhancement behind the posterior outline is representative of a simple cyst.** Adapted from Figure 7 of Bialek, EJ, Jakuboski W. Mistakes in ultrasound diagnosis of superficial lymph nodes. *J Ultrason*. 2017;17:59–65.

Table 14.2 BENIGN VERSUS MALIGNANT LYMPH NODES (LN)

SONOGRAPHIC TECHNIQUE	BENIGN LN	MALIGNANT LN
B-Mode	**Oval shape** **Regular border** **Hyperechoic hilum**	**Round Shape** **Unshaped border** **Loss of echogenic hilum** **Surrounding edema**

Adapted from: Chiorean L, Barr RG, Braden B, et al. Transcutaneous Ultrasound: Elastographic Lymph Node Evaluation. Current Clinical Applications and Literature Review. *Ultrasound in Medicine & Biology*. 2016;42(1):16-30.

epithelial tissue within intraparotid and periparotid LNs during the embryologic phase. Finding heterotopic parotid tissue located within parotid LNs can be indicative of Warthin's tumor and histopathologic assessment is recommended. The ultrasound of the parotid gland is performed by using a high-frequency linear transducer. The parotid gland is located in the retromandibular fossa and is anterior to the ear and sternocleidomastoid muscle. For the evaluation of tumors, the entire salivary glands must be imaged in 2 dimensions. The sonographer should scan throughout the neck to assess for LN or metastatic spread (see Figure 14.14).

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Keywords/Tags: Warthin's tumor

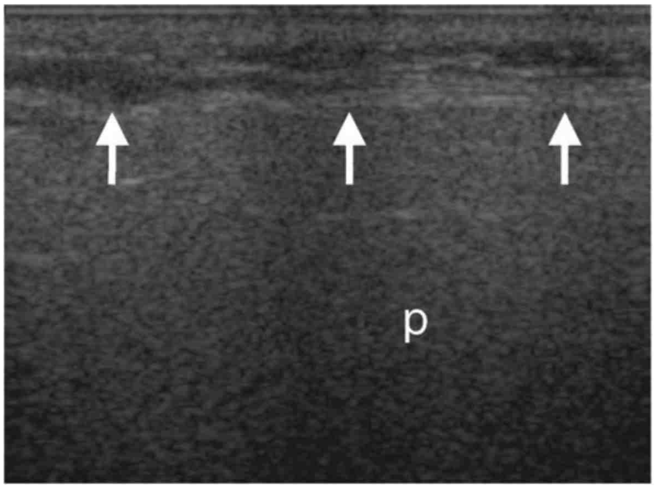

Figure 14.14 **Ultrasound image of the normal homogenous echotexture of a parotid gland (P) with distinct borders (arrows).** From Figure 1A of Hocevar A, Ambrozic A, Rozman B, Kveder T, Tomsic M. Ultrasonographic changes of major salivary glands in primary Sjogren's syndrome: diagnostic value of a novel scoring system. *Rheumatology.* 2005;44:768–772.

10. EXPLANATION

B. Tonsillitis is diagnosed by findings of enlarged tonsils that have a homogenous or striated appearance, while a PTA is demonstrated by enlarged tonsils that have a heterogeneous or cystic appearance. Ultrasound examination of normal tonsils appear as small, homogenous, oval structures that are typically 10 to 20 mm in length. By using intraoral ultrasound, the sonographer can distinguish whether the nature of the affected, enlarged tonsils is either homogenous or heterogeneous in nature by recognizing the palatopharyngeal muscle, the ECA, and air in the onopharynx. A normal tonsil is small (10–20 mm) with a triangular or oval structure and a homogenous low-level echogenic texture (Figure 14.15a) (Secko and Sivitz 2015). A homogenous or striated appearance is indicative of a tonsillitis (i.e., peritonsillar cellulitis) (Figure 14.15b), whereas a heterogeneous appearance would signify a PTA (Figure 14.15c). Furthermore, a PTA may displace or distort the tonsil medially and caudally with an anechoic fluid collection.

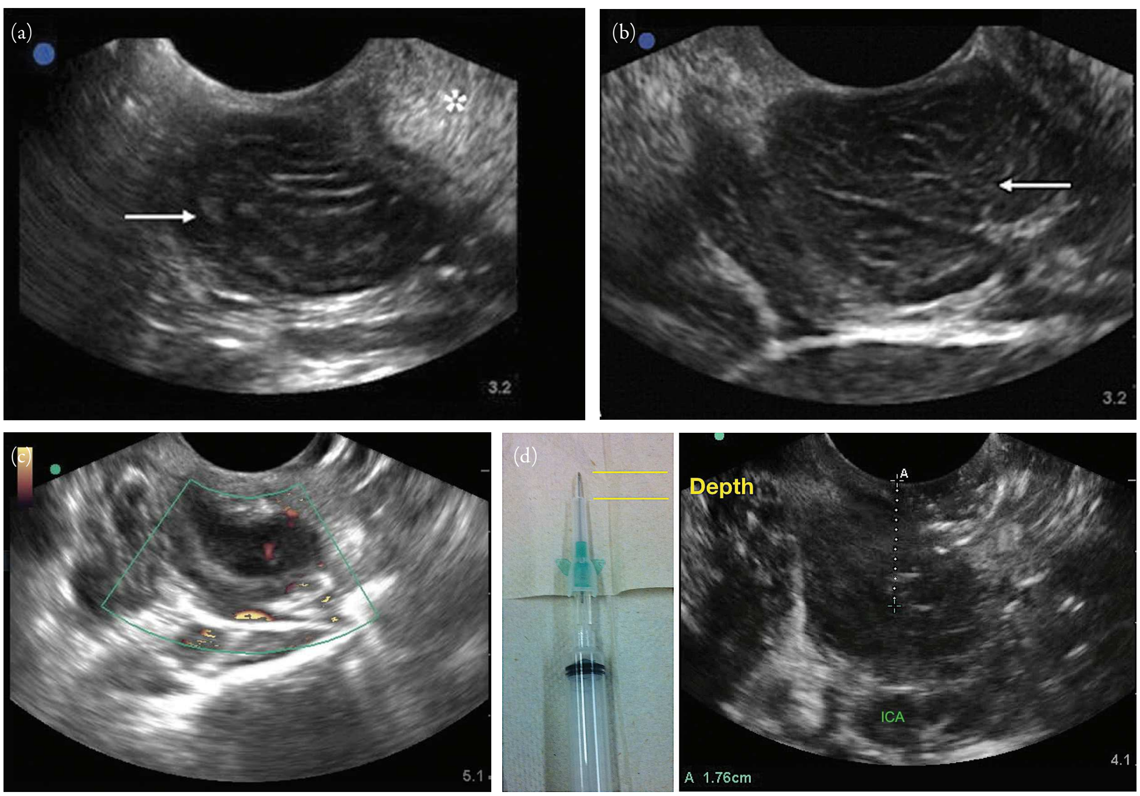

Figure 14.15 (a) **Intraoral ultrasound image of a normal tonsil (white arrow).** Adapted from Figure 1 of Secko M, Sivitz A. Secko M, Sivitz A. Think ultrasound first for peritonsillar swelling. *Am J Emerg Med*. 2015;33(4):569–572. (b) **Intraoral ultrasound image of a peritonsillar cellulitis.** Note the homogenous and striated appearance of the tonsil (white arrow). Adapted from Figure 2 of Secko M, Sivitz A. Secko M, Sivitz A. Think ultrasound first for peritonsillar swelling. *Am J Emerg Med*. 2015;33(4):569–572. (c) **Intraoral ultrasound image of a peritonsillar abscess.** Note the anechoic fluid collection with the tonsil (white arrow). The irregular border of the anechoic fluid collection is consistent with an abscess. Adapted from Figure 3 of Secko M, Sivitz A. Secko M, Sivitz A. Think ultrasound first for peritonsillar swelling. *Am J Emerg Med*. 2015;33(4):569–572. (d) **Measurement of depth needed to aspirate the peritonsillar abscess on ultrasound.** This can then be used to cut a similar length off the end of the needle cap, which can be used as a safety guide during the procedure to prevent inadvertent puncture of deeper vessels. Note the location of the internal carotid artery just posterior to the peritonsillar abscess.

The technique to determine whether a PTA is present is by using an endocavitary probe. The transducer is covered with a sterile sheath. Topical anesthetic should be sprayed in the posterior oropharynx. The transducer should come in contact with the tonsillar tissue. The tonsil in question should be scanned in 2 planes to help identify the presence of PTA. The depth needed to successfully aspirate the PTA can be estimated on ultrasound, and, in turn, the needle cap can be tailored to use as a safety guide to prevent inadvertent puncture into deeper structures (Figure 14.15d). Costantino et al. (2012) found that ultrasound was significantly better than landmark technique for correct diagnosis of PTA, successful aspiration, and reduction in computed tomography (CT) scans.

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Keywords/Tags: Peritonsillar abscess, tonsillitis

11. EXPLANATION

A. There is no evidence of an abscess in Figure 14.2a, but the green arrow in Figure 14.2b depicts a drainable abscess. The patient's presentation is concerning for possible facial abscess. CT scan is the usual modality to identify facial cellulitis versus abscess. In this case report by Lewis et al. (2014), the CT scan was negative for abscess but the clinicians were still concerned about facial abscess and performed a point-of-care ultrasound showing abscess (green arrow) above the maxilla (double arrows) (Figure 14.2b). The abscess was identified near the patient's globe. The diagnostic accuracy becomes especially important when ruling out facial abscess in the "danger triangle of the face," bordered by the corners of the mouth and the nasal bridge. Venous drainage in this area can in rare cases communicate in retrograde fashion to the brain via the cavernous sinus and lead to meningitis, encephalitis, intracranial abscess, and possible death (Lewis et al. 2014).

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Keywords/Tags: Facial abscess, facial cellulitis

12. EXPLANATION

D. Punctate echogenic foci without posterior shadowing. In patients presenting with an anterior neck mass, ultrasound can be useful to differentiate benign masses from malignancy. The primary feature of sonography associated with thyroid malignancy is the presence of calcifications. Punctate echogenic foci without posterior shadowing in a sonogram indicate microcalcifications and are heavily associated with malignancy (see Figure 14.16).

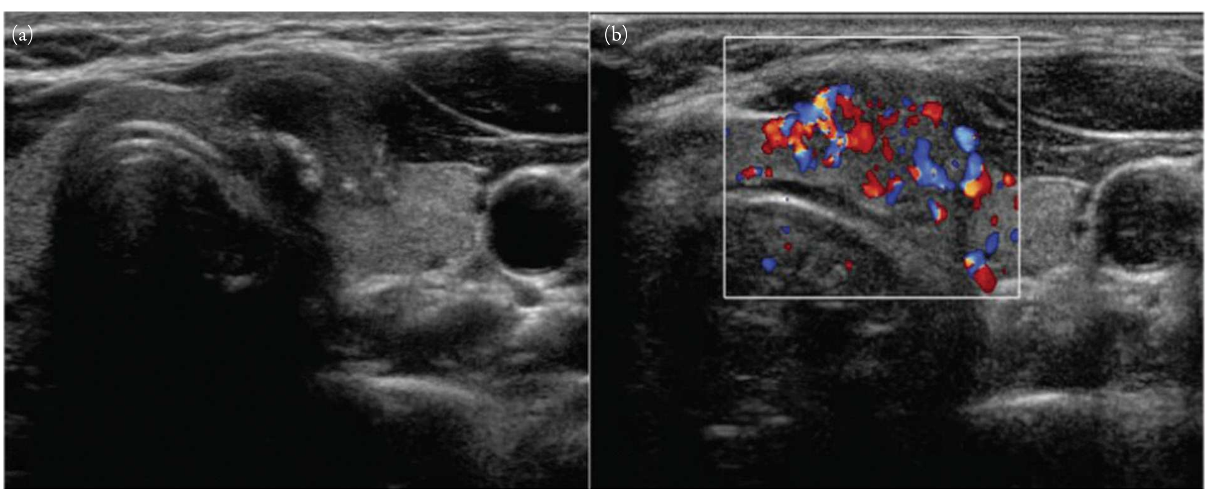

Figure 14.16 Image A shows a transverse view of a hypoechoic nodule with irregular outlines. Both coarse and microcalcifications are seen in this nodule. In Image B, Doppler flow shows diffuse vascularity within the entire nodule. Adapted from Figure 5 of Anil G, Hegde A, Chong FHV. Thyroid nodules: risk stratification for malignancy with ultrasound and guided biopsy. *Cancer Imag.* 2011;11:209–223. doi:10.1102/1470-7330.2011.0030.

The patterns of calcifications seen in the thyroid are microcalcifications, rim calcifications, and coarse calcifications. Compared with a noncalcified predominantly solid nodule, the presence of microcalcifications increases the cancer risk 3-fold, and coarse macro-calcifications increase cancer risk 2-fold. Microcalcifications are seen at ultrasound as tiny hyperechoic foci of around 1 mm with or without acoustic shadowing or as simple fine acoustic shadows. Benign thyroid lesions may mimic microcalcifications in thyroid malignancies, but the former can be distinguished from the latter if the comet tail or reverberation artefacts are appropriately demonstrated. Fine needle aspirations or surgical consultation is needed to definitively diagnose all nodules.

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Keywords/Tags: Thyroid ultrasound, thyroid cancer

13. EXPLANATION

A. The distance between the 2 echogenic lines representing the lumen-intima and the media-adventitia interface. The IMT has been used to evaluate cardiovascular risk factors. The presence of carotid artery plaques adds to the risk assessment. This test measures the thickness of the inner 2 layers of the carotid artery (the intima and media). The IMT is the distance between the 2 echogenic lines representing the lumen-intima and the media-adventitia interface. Measurement of IMT should occur in an area free of plaque to increase accuracy and reproducibility.

A full evaluation of this region includes visualization of the CCAs, ICAs, and ECAs (Figure 14.17a). The IMT is seen as a double line visualized in the CCA. The IMT should be measured along the far wall. A 10 mm length of straight arterial segment wall should be measured if the ultrasound has software that can average the IMT. A perpendicular measurement is made to estimate this value. IMT values of more than 0.9 mm should be considered abnormal (Figure 14.17b). Abnormal IMT values are associated with cardiovascular disease and linked to endpoints such as myocardial infarction and ischemic stroke (Naqvi and Lee 2014). IMT measurements can be used as a screening tool in asymptomatic patients with coronary heart disease risk factors (Touboul et al. 2012).

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Keywords/Tags: Carotid ultrasound, intima-media thickness

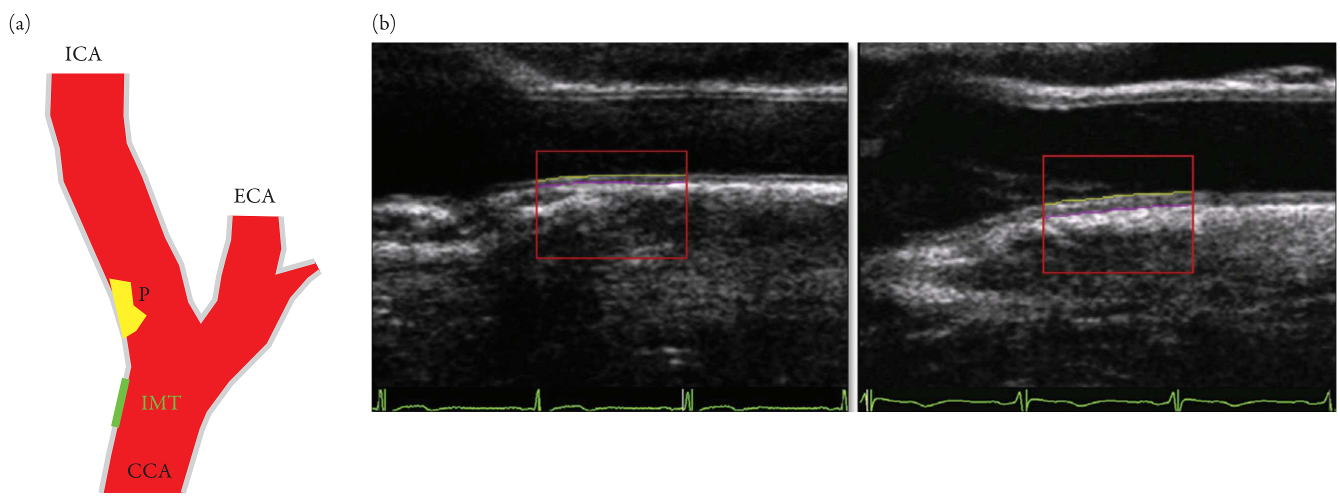

Figure 14.17 (a) **Schematic of the carotid bifurcation with common carotid artery (CCA), internal carotid artery (ICA) and external carotid artery (ECA).** The intima is represented by the gray tracing, with the intimal medial thickness measured over a straight 10 mm segment (intima-media thickness). There is a plaque (P) in the ICA. (b) **A longitudinal ultrasound image of the common carotid artery.** (a) Normal carotid artery intimal thickness of 0.58 mm. (b) There is diffuse increased common carotid artery intima-media thickness noted between the yellow and purple line. This patients intima-media thickness was measured as 1.05 mm. Adapted from Figure 1 of Naqvi TZ, Lee M-S. Carotid intima-media thickness and plaque in cardiovascular risk assessment. *JACC Cardiovasc Imaging.* 2014;7(10):1025–1038. doi:10.1016/j.jcmg.2013.11.014.

14. EXPLANATION

B. Right-sided central venous catheter insertion. Central venous catheter thrombosis is a common ultrasonographic finding of patients who have had central venous catheters, usually forming between the third and sixth day after central venous catheter insertion. Several factors increase risk of thrombus formation. This includes larger circumference catheters, multiple venipuncture attempts, and malpositioned catheters. The risk of thrombus is higher in patients with a catheter tip in the innominate vein or proximal vena cava as compared to the distal superior vena cava and right atrial junction. Patients with left-sided central venous catheters are also 3.5 times more likely to have thrombosis when compared to the right. This is due to the anatomy of the venous system in the upper torso. Specifically, the left brachiocephalic vein is long and has a sharper angle into the superior vena cava.

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Kujur R, Rao SM, Badwaik G, Paraswani R. Thrombosis associated with right internal jugular central venous catheters: a prospective observational study. *Indian J Crit Care Med*. 2012;16(1):17–21.

Keywords/Tags: Internal jugular vein thrombus

15. EXPLANATION

C. Evidence of posterior acoustic shadowing. The most common congenital mass in the neck is the thyroglossal duct cyst. Thyroglossal duct cysts are fluid-filled structures that often display evidence of acoustic enhancement, not acoustic shadowing. Cyst walls can appear thickened due to inflammation and cellular debris or as thin or even imperceptible. Longitudinal sonograms in patients with thyroglossal duct cyst can show a mixed echo pattern with thick septa and internal debris. Complex patterns in cysts can also lead to anechoic or pseudosolid appearances (see Figure 14.18). In patients with thyroglossal duct cysts, repeat outpatient monitoring is suggested to assess for ectopic thyroid tissue or signs of malignancy.

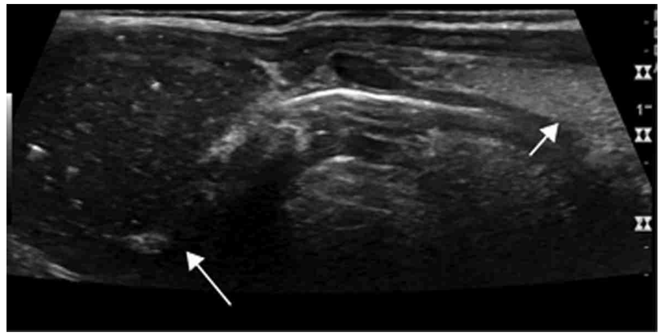

Figure 14.18 **Ultrasound image of a thyroglossal duct cystic mass (long arrow), located superior to the thyroid gland (small arrow).** Typically, these are midline, complex cystic masses with internal debris and a pseudosolid appearance. They are well-circumscribed, with through transmission and edge artifact. From Figure 130.4, Case 130 of Scoutt LM, Hamper UM, Angtuaco L, eds. *Ultrasound*. Oxford, UK: Oxford University Press; 2017.

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Zander DA, Smoker WRK. Imaging of ectopic thyroid tissue and thyroglossal duct cysts. *Radiographics*. 2014;34(1):37–50.

Keywords/Tags: Thyroglossal cyst

16. EXPLANATION

B. Hypoechoic, atrophy. Ultrasound can be used to identify salivary glands and assess for disease. When inflamed, salivary glands become enlarged and can have increased blood flow. Salivary glands are typically small, oval shaped, and hypoechoic. In patients with chronic inflammation such as Sjogren's syndrome, glands can atrophy. In patients with Sjogren's, salivary glands appear as small, scattered hypoechoic or anechoic lesions with increased parenchymal blood flow. The long-term inflammation of the salivary glands leads to evidence of inhomogeneity and isolated hypoechoic areas in the ultrasound (Figure 14.19). Inhomogeneity is also noticed in the submandibular glands, which may also suffer from adipose degeneration and atrophy in tandem with the parotid gland.

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Keywords/Tags: Sjögren's syndrome, immunology

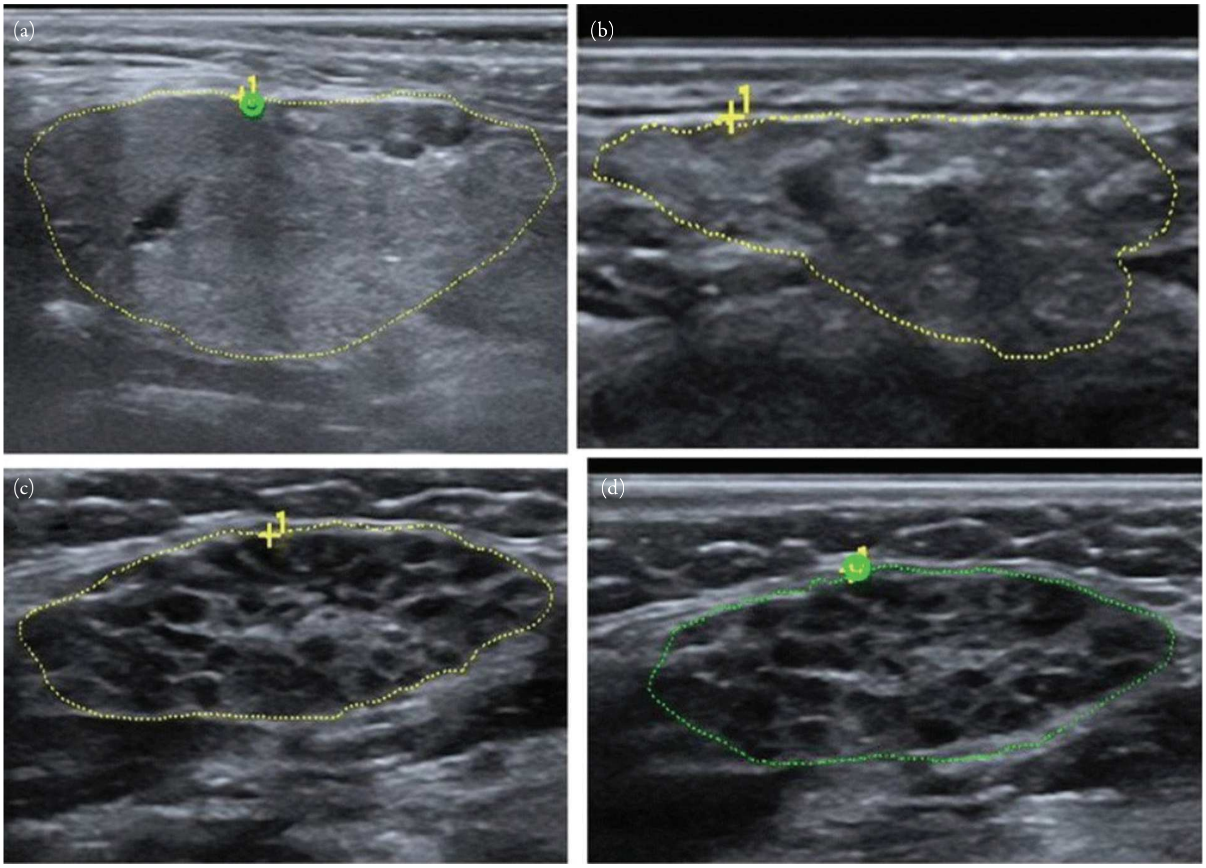

Figure 14.19 **Ultrasound image showing parenchymal inhomogeneity in the submandibular salivary glands.** (a) Normal submandibular gland. (b) Submandibular gland with evident inhomogeneity. (c) and (d) Submandibular glands with gross inhomogeneity. Adapted from Figure 1 of Baldini C, Luciano N, Tarantini G, et al. Salivary gland ultrasonography: a highly specific tool for the early diagnosis of primary Sjögren's syndrome. *Arthritis Res Ther*. 2015;17(1):146. doi:10.1186/s13075-015-0657-7.

17. EXPLANATION

C. Carotid artery focal wall thickening greater than 50% of the surrounding IMT or greater than 0.5 mm. Ultrasound evaluation of the carotid artery can be useful in determining cardiovascular outcomes. Notably, it can be used to track intima-media thickening with age or in patients with atherosclerosis, a change that is also associated with plaque formation. Identification of a carotid artery plaque can increase cardiovascular risk for patients. B-mode ultrasound can clearly visualize the layers of the carotid artery and distinguish between its layers. The finding of a focal hyperechoic structure with the arterial lumen is concerning for a carotid plaque. By definition, a carotid plaque must be greater than 0.5 mm or at least 50% of the surrounding IMT (see Figure 14.20). Additionally, carotid plaques can be seen when the surrounding IMT demonstrates wall thickness greater than 1.55 mm, measured from the intima-lumen interface to the media-adventitia interface. These measurements serve as definitions for classification of carotid lesions. The presence of carotid plaque is correlated with an increase ischemic stroke risk of 1.5-fold. In addition, in elderly men, the presence of 1 to 2 plaques increased mortality risk 2.9-fold, and the presence of greater than 4 plaques was associated with a 4.9-fold increased mortality risk (Park 2016).

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Touboul PJ, Hennerici MG, Meairs S, et al. Mannheim Carotid Intima-Media Thickness and Plaque Consensus (2004-2006-2011). *Cerebrovasc Dis*. 2012;34:290–296.

Keywords/Tags: Carotid plaque

18. EXPLANATION

D. All of the above. Ultrasound has been shown to be superior to plain film radiographs in the evaluation of maxillofacial fractures. Specifically, the sensitivity and specificity of ultrasound for nasal bone fractures is 98% and 95%, respectively. A linear, high-frequency probe is used to visualize these structures due to their superficial

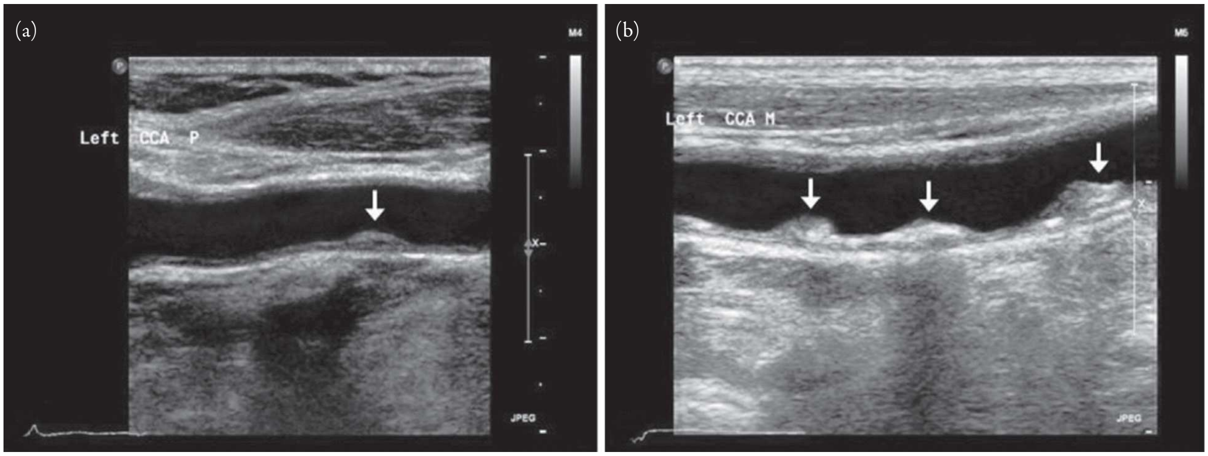

Figure 14.20 **A carotid ultrasound showing carotid plaques in two patients.** (a) shows a single asymptomatic plaque which is low risk. The image has an arrow pointing to a smooth, homogenous plaque and (b) shows moderate to large amount of heterogeneous plaques with irregular surfaces. Adapted from Figure 1 of Park TH. Evaluation of carotid plaque using ultrasound imaging. *J Cardiovasc Ultrasound*. 2016;24(2):91–95.

nature. The findings seen on ultrasound include cortical irregularity, interruption of continuity of bony structures, and soft tissue swelling of the nasal lateral walls (Figure 14.21a, Figure 14.21b). If there is the absence of soft tissue edema, a cortical irregularity can also be seen in nerve foramen. Evaluation of the contralateral side for similar anatomy may help make the distinction between a fracture and a nerve foramen.

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Keywords/Tags: Nasal bone fracture, supine position, linear high-frequency probe

19. EXPLANATION

D. Start IV antibiotics and anticoagulation then admit for inpatient management. This patient has Lemierre's syndrome. Lemierre's syndrome is an infectious thrombophlebitis of the internal jugular vein. This can be caused by a bacterial pharyngitis and result in septic emboli. Lemierre's syndrome most often occurs when a pharyngitis progresses to a PTA and the abscess wall ruptures internally. This can

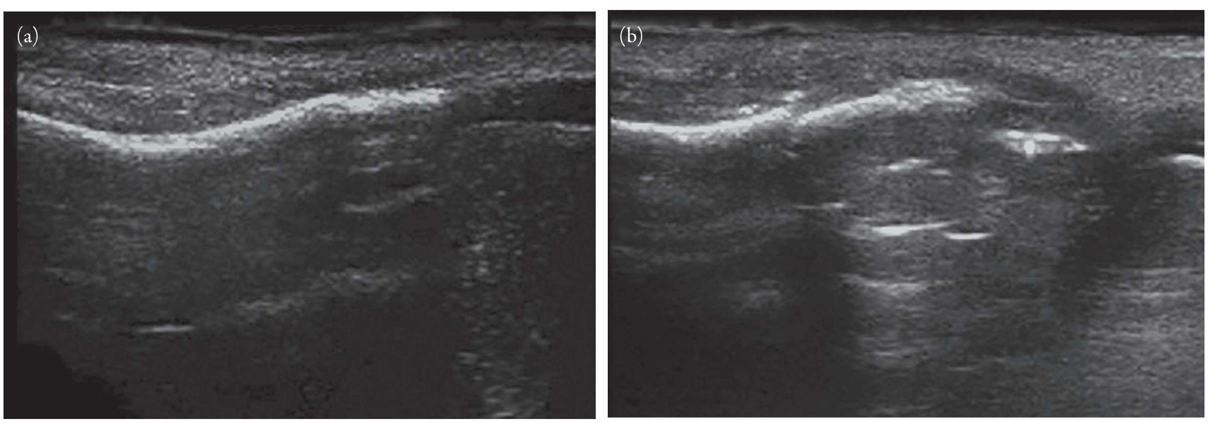

Figure 14.21 (a) **Ultrasound image of normal nasal bone.** Note the hyperechoic bony structure that is intact. Adapted from Figure 3 of Caglar B, Serin S, Akay S, et al. The accuracy of bedside USG in the diagnosis of nasal fractures. *Am J Emerg Med*. 2017;35(11):1653–1656. doi:10.1016/j.ajem.2017.05.015. (b) **Ultrasound image of nasal bone fracture.** Note the hyperechoic bony structure with cortical disruption and mild superficial edema. Adapted from Figure 4 of Caglar B, Serin S, Akay S, et al. The accuracy of bedside USG in the diagnosis of nasal fractures. *Am J Emerg Med*. 2017;35(11):1653–1656. doi:10.1016/j.ajem.2017.05.015.

lead to infection of the nearby internal jugular vein, ultimately leading to a thrombophlebitis. Infections require broad spectrum antibiotics, anticoagulation, and hospital admission. Ultrasound can be used to evaluate patients with suspected Lemierre's syndrome. Since Lemierre's syndrome leads to thrombophlebitis in the internal jugular vein, abnormalities in one vein compared to the other can be useful in diagnosis. Particularly, the vein should be dilated, have a lumen with an echogenic thrombus, and be deprived of blood flow. Generally, the vein should be noncompressible. Figure 14.4 shows a concentric echogenic material within the lumen of the internal jugular vein as well as increased soft-tissue edema surrounding the vein. These findings confirm presence of thrombus in the internal jugular vein with surrounding inflammation. Choice A is incorrect since discharge with oral antibiotics is inadequate treatment. Choice B is incorrect since a head CT does not help in the management of this patient. Choice C is incorrect since this is an infected thrombus, and first-line treatment will be IV antibiotics and IV anticoagulation.

REFERENCE

Castro-Marín F, Kendall JL. Diagnosis of Lemierre's syndrome by bedside emergency department ultrasound. *J Emerg Med*. 2010;39(4):436–439.

Keywords/Tags: Lemierre's syndrome, internal jugular vein, color Doppler ultrasound, thrombophlebitis

20. EXPLANATION

C. Continue with central line placement of the right internal jugular vein. The image shows a guidewire within the internal jugular vein. Ultrasound is a useful modality for assisting in the establishment of central venous access by visualizing underlying vasculature. The internal jugular vein can be easily visualized using a linear probe placed on the antero-lateral neck. Veins often have leaflets that can be easily visualized on B-mode ultrasound. This should not preclude central line placement in those vessels but should make the clinician aware of the possibility of some resistance of inserting the guidewire when it hits the valve. Choice A is incorrect since the guidewire is in the right location. Choice B is incorrect since it is okay to proceed with right internal jugular vein cannulation. Choice C is incorrect because no thrombus is shown.

REFERENCE

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Keywords/Tags: Central line, guidewire

21. EXPLANATION

A. A JVP of 6 cm is considered normal. Socransky et al. (2010) performed ultrasound to evaluate the JVP in normal patients and found that the normal ultrasound-JVP is 6.35 cm. This is slightly lower than the normal JVP on physical exam of 8 cm. Calculation of the ultrasound-JVP is performed by placing the patient with the head of the bed at 45 degrees and the legs parallel to the ground. A linear probe is placed on the neck with the indicator toward the patient's head to visualize the internal jugular vein in long axis. The height of the internal jugular vein is measured by the vertical distance between the top of the jugular venous pulse (black arrow) and the sternal angle with the patient holding his breath at the end of expiration (Figure 14.22). Ultrasound-JVP distance calculated by adding an additional 5 cm to the measured height of the internal jugular vein (Socransky et al. 2010; Siva et al. 2012). Ultrasound-JVP distance has been found to correlate with invasive CVP measurements and able to predict patients in a fluid overloaded state (Siva et al. 2012; Jang et al. 2004).

Learning Points: Normal ultrasound-JVP distance is 6.35 cm or less.

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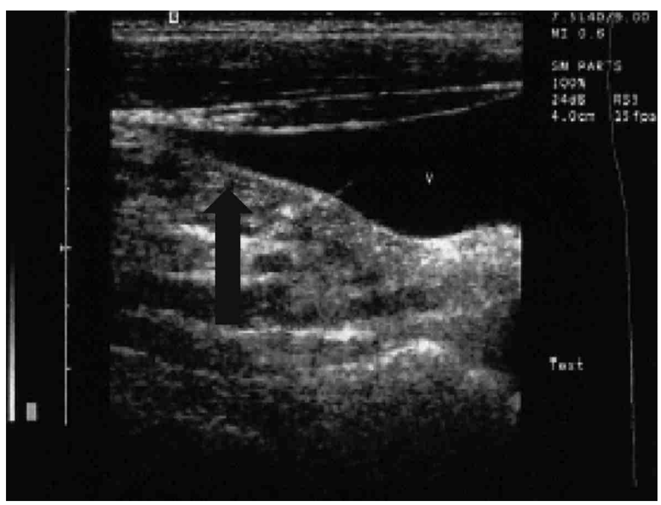

Figure 14.22 **Longitudinal view of the internal jugular vein showing the tapering (black arrow) of the vein in jugular vein distension assessment.** Adapted from Figure 1 of Siva B, Hunt A, Boudville N. The sensitivity and specificity of ultrasound estimation of central venous pressure using the internal jugular vein. *J Crit Care*. 2012;27(3):315.e7–315e11. doi:10.1016/j.jcrc.2011.09.008.

Siva B, Hunt A, Boudville N. The sensitivity and specificity of ultrasound estimation of central venous pressure using the internal jugular vein. *J Crit Care*. 2012;27(3):315.e7–e11.

Socransky SJ, Wiss R, Robins R, Anawati A, Roy M-A, Yeung IC. Defining normal jugular venous pressure with ultrasonography. *CJEM*. 2010;12(4):320–324.

Keywords/Tags: Central venous pressure, internal jugular vein, jugular venous pressure

15.

DEEP VENOUS THROMBOSIS AND VENOUS THROMBOEMBOLISM

Michael I. Prats, David P. Bahner, Creagh T. Boulger, and Michael R. Go

QUESTIONS

1. A 52-year-old woman presents to the clinic with right leg swelling and mild calf tenderness. She has a history of hypertension, hyperlipidemia, and a remote history of uterine cancer. She currently on estrogen supplementation. Her vital signs are unremarkable. On exam, you find mild right calf tenderness and asymmetric edema. You perform a point-of-care ultrasound (POCUS), seen in Figure 15.1 and Video 15.1. How common is deep venous thrombosis (DVT) in the United States?

Figure 15.1

A. 5/100,000
B. 50/100,000
C. 500/100,000
D. 1,000/100,000

2. A healthy 35-year-old woman presents with calf pain after an 8-hour flight home. Her vital signs are temperature 98.8°F, blood pressure 128/81, heart rate 94, pulse oximetry 98%, and respiratory rate 14. She has no cardiac or respiratory symptoms. On exam, you find asymmetric swelling with mild tenderness over the right calf. You order a serum D-dimer which is mildly elevated. You perform a POCUS of the right lower extremity and see the images in the greater saphenous vein seen in Figure 15.2 and Video 15.2. What is an indicated next step in diagnosis or management?

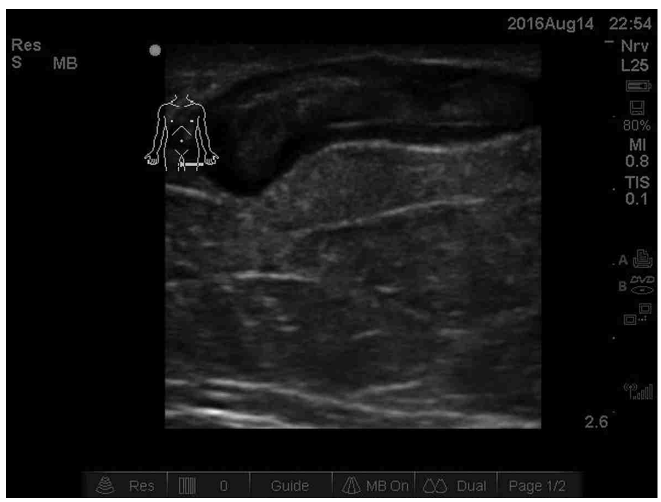

Figure 15.2

A. Anticoagulation for 12 months
B. Repeat ultrasound in 1 week
C. Computed tomography (CT) venogram
D. Repeat D-dimer

3. A 72-year-old man presents with shortness of breath and bilateral leg swelling. His vital signs are blood

pressure of 172/98, heart rate of 109, respiratory rate of 18, pulse oximetry of 92%, and temperature of 98.9°F. His lungs sound clear to auscultation. You notice on your exam that he has bilateral pitting edema and erythema to his lower extremities. His left lower extremity has markedly increased swelling compared to the right. You determine you need to rule out a DVT. Which probe should you choose to evaluate for DVT and what diagnostic feature of the exam are you primarily assessing?

A. Phased array + Compression
B. Linear + Compression
C. Phased array + Augmentation
D. Linear + Augmentation

4. A 46-year-old man presents to the emergency department with chest pain. He notes sharp pain, worsened with deep breaths. He recently returned from a flight to China. His vital signs show a blood pressure of 142/90, heart rate 121, respiratory rate 22, pulse oximetry 88%, and temperature 97.9°F. He is tachypneic. There are normal lung sounds on auscultation. You note diffuse right leg swelling. Which of the following vessels is most likely to contain a thrombus?

A. Deep femoral vein
B. Femoral vein
C. Posterior tibial vein
D. Common femoral vein

5. You have a 32-year-old female who presents with dyspnea and left calf pain. Her vital signs are blood pressure 82/65, heart rate 133, respiratory rate 24, pulse oximetry 92% on 4 L/min by nasal cannula, and temperature 98.6°F. You are concerned that she could have a PE. The patient is unable to get a CT scan at this time due to her instability and inability to lay flat. You perform a bedside cardiac ultrasound to assess for findings of right heart strain. All of the following findings would be concerning for right heart strain *except*:

A. Right ventricle (RV) : Left ventricle (LV) ratio 1:1.
B. Mitral annular plane systolic excursion (MAPSE) of 1 cm.
C. Severe tricuspid regurgitation (TR).
D. Plethoric inferior vena cava (IVC).

6. A 75-year-old male presents to the emergency department with left groin and thigh pain. You are on an ultrasound scanning shift with an intern and are asked to evaluate for a DVT. The intern begins in the groin and finds a noncompressible vessel. A thrombus in which of the following vessels would *not* be considered a DVT?

A. Profunda femoris vein
B. Common femoral vein
C. Superficial femoral vein
D. Greater saphenous vein

7. A 22-year-old female presents to the emergency department with left calf swelling. She notes she started oral contraceptives 2 months ago. You ask your medical student to meet you in the room to perform a DVT ultrasound. When you arrive, you find the medical student, kneeling next to the patient with the ultrasound machine, sliding the pant legs of the patient's jeans over her knee while she is sitting in a chair. What is the ideal position for the patient when performing a DVT exam?

A. Upright
B. Supine with bent knees
C. Supine with frog leg positioning
D. Trendelenburg

8. A 36-year-old female presents with leg swelling after a cross-country car ride. You recognize her as one of the medical school anatomy instructors. Her vital signs are normal. She has no chest pain or shortness of breath. You perform an ultrasound to assess for DVT. There is no evidence of thrombus in the thigh veins. As you begin scanning the popliteal vein, the patient asks you to point out the veins that form the popliteal vein. Which of the following does *not* drain into the popliteal vein?

A. Anterior tibial vein
B. Peroneal vein
C. Greater saphenous vein
D. Gastrocnemius vein

9. A 41-year-old woman presents to your community emergency department with chest pain. She is morbidly obese and weighs approximately 220 kg. She states that she is bed-bound, but for the past few days she has been having a sharp central chest pain, associated with dyspnea at rest. She has bilateral leg swelling but thinks that the right side may be worse than the left. Her vital signs show a blood pressure of 162/94, heart rate of 123, a pulse oximetry of 91%, and temperature of 98.3°F. You are suspicious for a PE and order a CT scan of the pulmonary arteries. Your CT technician calls you a few minutes later to tell you that this patient will not fit in your CT. Ventilation-perfusion scanning is not available. You call to transfer the patient to a nearby large referral center and they recommend checking for a DVT prior to transfer and initiating anticoagulation if positive. You note normal compressibility in the right common femoral and femoral veins but are having difficulty

visualizing the popliteal vein due to the patient's obesity. All of the following maneuvers may optimize visualization *except*:

A. Slight flexion of the knee.
B. Sosterior approach with the probe.
C. Sugmentation and Valsalva.
D. Power Doppler.

10. A 40-year-old male presents with a red, swollen, painful right calf. He is otherwise healthy. Vital signs are a blood pressure of 140/84, heart rate of 92, respiratory rate of 16, pulse oximetry of 95%, and a temperature of 98.9°F. Your medical student has evaluated the patient and is concerned for a DVT. On examination, the patient has significant right calf tenderness. You perform a bedside ultrasound and obtain the images shown in Figure 15.3 and Video 15.3. What is the most likely diagnosis?

Figure 15.3

A. DVT
B. Cellulitis
C. Abscess
D. Pseudoaneurysm

11. A student is presenting a case to you of a patient she just evaluated in the emergency department. She describes a 45-year-old man with diffuse leg pain. His vital signs are unremarkable. On exam, there is mild tenderness to the right calf on palpation. The student states that she has already performed a bedside ultrasound to evaluate for DVT. She shows you the images in Figure 15.4 and Video 15.4 and concludes that there is not a DVT. How do you respond?

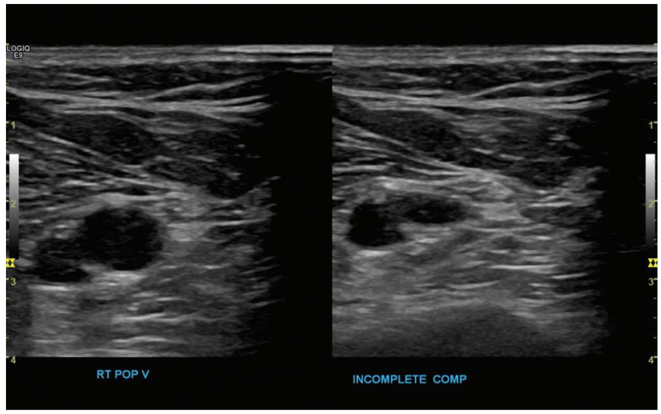

Figure 15.4

A. Correct, it collapses so there is not a DVT.
B. Incorrect, you did not use augmentation so we cannot rule out DVT.
C. Incorrect, we did not see the walls touch so we cannot make any conclusions.
D. Correct, although ultrasound is not sensitive enough to rule out this diagnosis.

12. As part of a quality assurance process, you are reviewing the ultrasound images on a 40-year-old cancer patient who presented to the emergency department with worsening left leg swelling. Upon chart review, you find that he has a history of lower extremity DVTs and has been on anticoagulation. The initial physicians were concerned for a DVT and performed a bedside ultrasound (see Figure 15.5, Video 15.5). The provider concluded there was no DVT based on these images. Do you agree, and why?

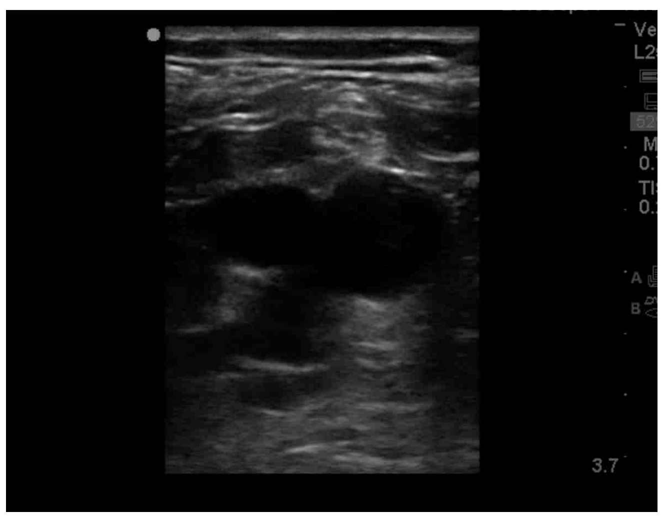

Figure 15.5

A. Agree—clots are hypo- or hyperechoic so an anechoic vessel rules out clot.
B. Disagree—clots are always anechoic.
C. Agree—a patent lumen is visualized.
D. Disagree—these images are not adequate.

13. A 25-year-old woman develops left leg and thigh swelling. She is 34 weeks pregnant and has no medical history. She denies chest pain or shortness of breath. Her vital signs are blood pressure 108/74, heart rate 85, pulse oximetry 97%, respiratory rate 16, and temperature 98.9°F. A lower extremity venous duplex is performed and determined negative for DVT. Which of the following statements is true?

A. Pelvic DVTs are adequately assessed with lower extremity ultrasound.
B. Empiric anticoagulation in this setting of high suspicion for DVT is indicated.
C. Pelvic DVT are rare and unlikely in this case.
D. This patient needs an magnetic resonance imaging (MRI).

14. In continuing your care for the patient in Question 13, you elect to obtain further studies. You are informed that there is a backup and it will be an hour until the patient is able to have the study performed. You attempt to directly interrogate the IVC and pelvic veins, but the field of view is obscured by bowel gas. Since you are unable to directly visualize the proximal vessels, you attempt to gain additional information from the lower extremity veins. Adjunctive maneuvers to indirectly detect proximal DVT include all of the following *except*:

A. Loss of phasicity.
B. More force required to compress distal veins.
C. Monophasic waveforms in the common femoral vein.
D. Reflux in the common femoral vein.

15. A 32-year-old female presents to the emergency department with left thigh pain and swelling. She has no medical history. She does not take any medications. She denies any personal or family history of VTE. Her vital signs are blood pressure 112/74, heart rate 74, respiratory rate 16, pulse oximetry 98%, and temperature 98.8°F. Physical exam reveals a clearly swollen left lower extremity, with mild erythema and tenderness of the thigh. She is found to have a left iliac vein DVT on CT venogram. What is the most appropriate treatment option?

A. Elevation, compression, 3 months of anticoagulation, and cessation of oral contraceptives
B. Thrombolysis with iliac vein stenting and 3 months of anticoagulation
C. Thrombolysis and 3 months of anticoagulation
D. Intravascular ultrasound is needed prior to determining appropriate therapy

16. A 75-year-old man presents with chest pain and shortness of breath. He has a history of hypertension, prostate cancer, and prior DVT in right lower extremity. His vital signs show blood pressure 154/92, heart rate 124, respiratory rate 20, pulse oximetry 88%, and temperature 99.4°F. On exam, his left lower extremity is much larger than his right. A bedside ultrasound for DVT using a 2-point exam was found to be negative. Given that the practitioner used this protocol, what percentage of DVTs are likely to be missed?

A. <10%
B. 15%
C. 20%
D. 30%

17. A 17-year-old female presents with right leg pain. She just started taking oral contraceptive pills. She denies any chest pain, shortness of breath, palpitations, or hemoptysis. Her vital signs are normal. She has a POCUS performed of the popliteal vein (see Figure 15.6 and Video 15.6). As you are discussing the diagnosis and treatment with her, she reveals that she suspected it might be a blood clot and after reading on the Internet, she is worried that she will get a PE. How will you counsel her regarding her risk for PE?

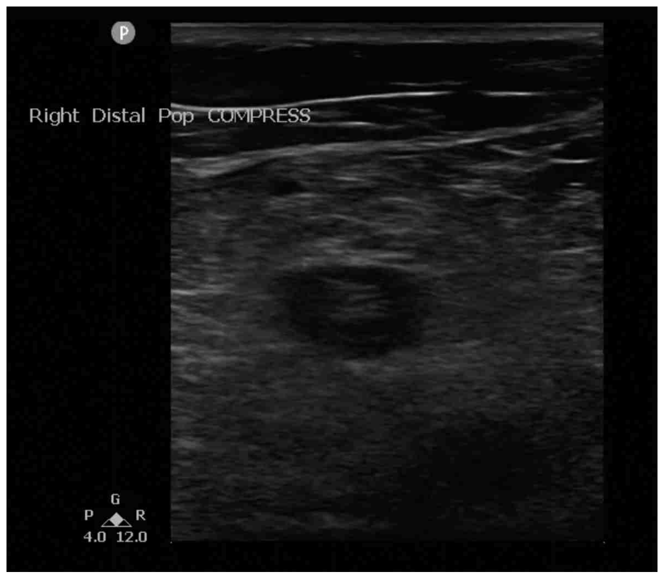

Figure 15.6

A. Many DVTs lead to PE, but if they are asymptomatic it does not matter.
B. Very few DVTs progress to PE even without treatment.
C. Once anticoagulated, the risk of PE is fairly low.
D. We can place an IVF filter to avoid getting a PE.

18. A 45-year-old male presents to the emergency department with right leg pain. He states he bumped his lower leg on the car door 1 week ago and now is having continued pain and some swelling. His vital signs are within normal limits. On exam, you find that his

right calf appears larger than his left. In addition, he has calf tenderness. You perform a bedside ultrasound to assess for DVT. When applying color Doppler you see the images in Figure 15.7 and Video 15.7. What is the name of this finding?

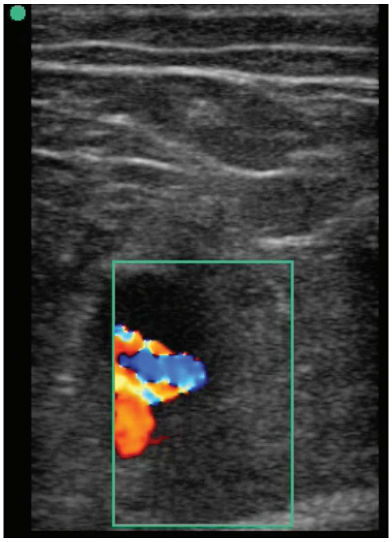

Figure 15.7

A. To and fro pattern
B. Augmentation
C. Coaptation
D. Compression

19. A 65-year-old female presents to your emergency department from a nursing home. She has a history of dementia and frequent falls. She had a left femoral neck fracture that was repaired 2 weeks ago. She is now having increased pain in her left leg. Her vital signs are blood pressure 156/88, heart rate 94, respiratory rate 18, pulse oximetry 94%, and temperature 96.9°F. You are on an ultrasound scanning shift, along with an ultrasound fellow, 3 residents, and 2 medical students. You are asked to perform an ultrasound to assess for DVT. The resident notices the lack of compressibility in the left common femoral vein and diagnoses a DVT. The rest of your eager team want to repeat the examination in order to gain experience with this ultrasound diagnosis. What is the most appropriate response?

A. Absolutely, educational scans are necessary for learning.
B It is better not to as there is a risk of clot mobilization.
C. Repeat examinations assist in clot breakdown.
D. The only concern is that this will cause the patient pain.

20. A 23-year-old female presents to the emergency department complaining of chest pain and difficulty in catching her breath. She is pregnant at 12 weeks gestation. She also states that she has had crampy pain in her left calf for the past 1 week. Her vital signs are blood pressure 108/70, heart rate 101, respiratory rate 18, pulse oximetry 98%, and temperature 99.4°. You are concerned that the patient could have a PE. The next best diagnostic test is:

A. Ventilation/perfusion scan.
B. CT pulmonary angiography.
C. MRI pulmonary angiography.
D. Venous ultrasound.

21. A 25-year-old male presents to the emergency department with a red painful swollen leg. He notes minor trauma to his leg 1 week ago. His vital signs are blood pressure 127/84, heart rate 92, respiratory rate 14, pulse oximetry 98%, and temperature 99.1°F. On exam his thigh and calf are swollen, erythematous, and tender to palpation. You perform an ultrasound to assess for DVT and find the images in Figure 15.8a, Figure 15.8b, and Video 15.8. What is the next step in diagnosis or treatment?

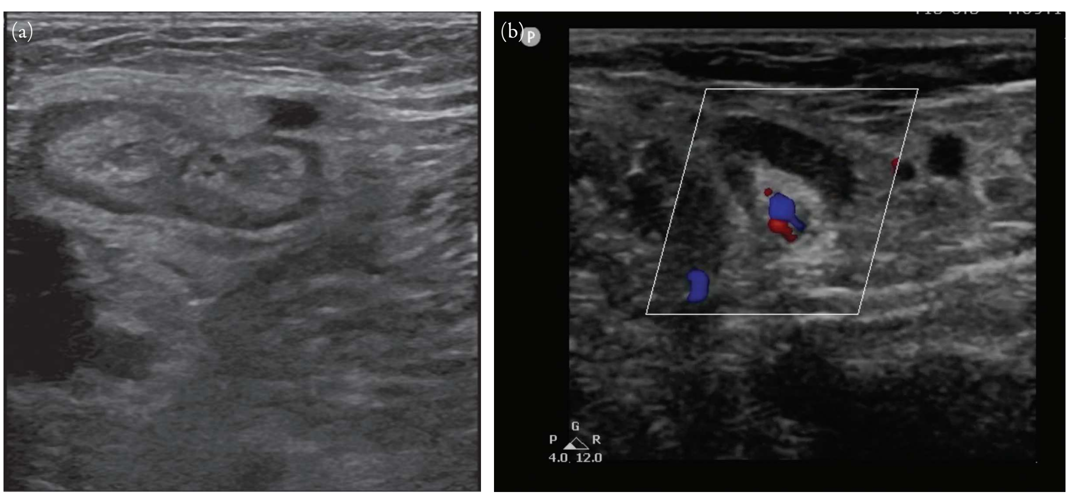

Figure 15.8

A. Start anticoagulation
B. Vascular consultation
C. Incision and drainage
D. Assess for an infectious etiology

22. You are working a night shift when the medics bring in a 34-year-old woman in respiratory distress. The medics state that she was in a car accident 2 weeks ago and had surgery for an ankle fracture. Her initial vital signs are blood pressure 98/65, heart rate 118, respiratory rate 22, pulse oximetry 96%, and temperature 98.6°F. You begin resuscitation and eventually order a CT pulmonary angiogram because you are concerned for PE. Lab work comes back showing normal troponin and normal pro-brain natriuretic peptide. You soon get a call from a radiologist stating that the patient has large bilateral pulmonary emboli. He states there is no evidence of right heart strain on CT. You consider the utility of performing a bedside echo. Which statement is accurate regarding the evaluation of right ventricular dysfunction with POCUS in PE?

A. POCUS is more sensitive than CT for right heart strain.
B. POCUS is more sensitive than laboratory values for right heart strain.
C. POCUS is more sensitive than ECG for right heart strain.
D. All of the above.

23. You are moonlighting in a rural emergency department when a patient is brought in for acute chest pain. You find a 65-year-old male patient who appears uncomfortable. You determine he has a history of DVT and PE and was taken off anticoagulation recently due to rectal bleeding. His initial vital signs are blood pressure 112/74, heart rate 121, respiratory rate 18, pulse oximetry 92%, and temperature 97.5°F. On his exam, his lungs are clear, and you hear a tachycardic heart without murmurs or other abnormalities. His electrocardiogram shows nonspecific T wave changes. You perform a chest X-ray that is normal. His lab work shows a normal troponin. A CT scan is performed showing a PE in the right main pulmonary artery. You perform a bedside ultrasound, show in Figure 15.9. Which of the following can be inferred from this measurement?

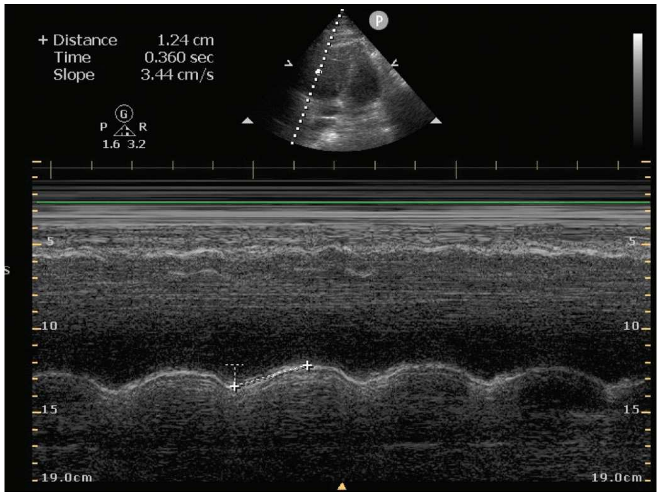

Figure 15.9

A. This patient has tamponade.
B. This patient has left heart failure.
C. This patient has a poor prognosis.
D. This patient has a massive PE.

24. A 54-year-old woman presents to the emergency department complaining of left calf pain that began a few hours ago. Her vital signs show a blood pressure of 145/84, heart rate of 75, respiratory rate of 12, pulse oximetry of 96%, and temperature of 98.7°F. On exam you note significant swelling of the left calf compared to the right, with tenderness on palpation. You perform a bedside ultrasound and obtain the image in Figure 15.10a and Figure 15.10b. The most appropriate next step in management is:

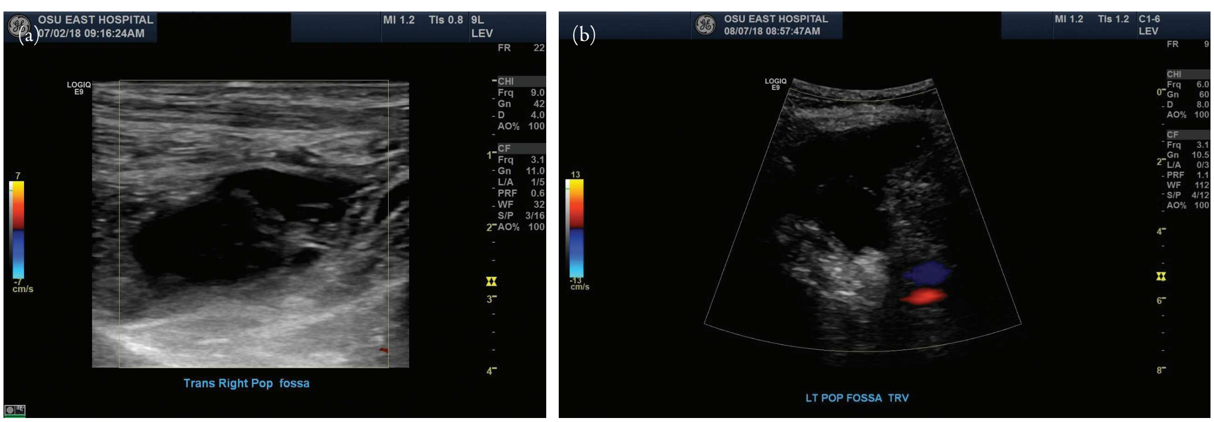

Figure 15.10

A. Anticoagulation.
B. Incision and drainage.
C. Reassurance and nonsteroidal anti-inflammatory drugs (NSAIDs).
D. Consult vascular surgery.

25. A patient presents to the emergency department in significant respiratory distress. He is an elderly male, pale, tachypneic, diaphoretic. As he is brought to a room you call the respiratory therapist to start noninvasive positive pressure ventilation. The patient's wife tells you that he has a history of primary arterial hypertension, but he has been taking all of his medications as prescribed. She notes that they did recently return from Brazil on an 8-hour flight. His vital signs are blood pressure 146/85, heart rate 122, respiratory rate 24, pulse oximetry 91% on a non-rebreather mask, and temperature 98.9°F. On examination, you note clear lungs. You are concerned that the patient could have a PE. You perform a focused bedside echo. Which of the following findings might help you distinguish an acute PE from a more chronic process?

A. TAPSE
B. McConnell's sign
C. RV wall thickness
D. RV:LV ratio

26. A 35-year-old female presents to the emergency department with pleuritic chest pain that began last night. She has no medical history. Her vital signs are a blood pressure of 100/72, heart rate of 115, respiratory rate of 16, pulse oximetry of 91%, and temperature of 100.0°F. Her lab work and EKG are pending. You perform a bedside ultrasound of her heart, which is shown in Figure 15.11 and Video 15.9. What is the most accurate way to interpret this finding?

A. This is a sign of right heart dysfunction.
B. This is pathognomonic for acute PE.
C. This is a nonspecific sign but could represent pericarditis.
D. This finding is specific for chronic pulmonary hypertension.

27. A 62-year-old female presents with acute worsening of her chronic dyspnea. She has a history of lung cancer with metastases to the brain. She has had multiple pulmonary emboli in the past and has resultant pulmonary hypertension. She states that she has been more out of the breath with exertion over the past 1 week. She is also having worsening chest pain. Her initial vital signs show a blood pressure of 124/86, heart rate of 107, respiratory rate of 18, pulse oximetry of 90% on room air, and temperature of 97.6°F. You are taking care of this patient with a medical student and suggest that she perform a bedside cardiac ultrasound to look for right heart strain. The medical student asks how the ultrasound can help if the patient has abnormal RV due to her chronic disease. Your response is:

A. If we see no pathology, ultrasound will still be useful in ruling out PE.
B. RV dilation will still be useful in this patient.
C. TAPSE will still be useful in this patient.
D. TR will still be useful in this patient.

28. You are working at an academic center with a medical student when a 34-year-old woman presents with shortness of breath. Her vital signs are blood pressure 115/75, heart rate 78, respiratory rate 12, pulse oximetry 98%, and temperature 98.6°F. Your medical student asks if he can evaluate the patient. He soon returns and states he performed a bedside ultrasound and is concerned that the patient has a PE with right ventricular strain based on his images (see Figure 15.12, Video 15.10). What is the next step?

Figure 15.11

Figure 15.12

A. Order CT angiography to confirm.
B. Activate the cath lab.
C. Anticoagulate the patient.
D. Repeat the images.

29. A 45-year-old female presents to the outpatient clinic with gradual onset of bilateral lower extremity swelling. Vital signs show a blood pressure of 154/90, heart rate of 84, respiratory rate of 14, pulse oximetry of 95%, and temperature of 97.8°F. You suspect venous reflux and perform a lower extremity venous ultrasound. Techniques to maximize the detection of reflux in this patient include all of the following *except*:

A. Reverse Trendelenburg position
B. A warm exam room
C. Augmentation and Valsalva
D. Direct visualization of incompetent valves on B-mode

30. A 64-year-old female presents to the emergency department with shortness of breath. She recently had a colon resection for adenocarcinoma. Her initial vital signs show temperature 99.4°F, blood pressure 122/79, heart rate 112, respiratory rate 18, and pulse oximetry 90%. You perform a lung ultrasound and obtain the image seen in Figure 15.13 and Video 15.11. What is the most likely diagnosis?

Figure 15.13

A. Pneumothorax
B. Pneumonia
C. Lung metastasis
D. PE

ANSWERS

1. EXPLANATION

B. 50/100,000. Venous thromboembolism (VTE) is a common disorder. Population studies have shown the incidence of DVT ranges from 45–117 per 100,000 person-years (Silverstein et al. 1998; Heit et al. 2016). The incidence of pulmonary embolism (PE) with or without a DVT ranges from 29–78/100,000 person-years (Heit et al. 2016). Overall incidence has declined, but there is increased incidence among elderly females. Other risk factors are important to recognize and include patient age, obesity, hospitalization for surgery or acute illness, nursing-home confinement, active cancer, trauma or fracture, immobility, pregnancy, and exogenous estrogen therapy (Heit et al. 2016). One study showed that 73.7% of VTE will present as outpatients (Spencer et al. 2007). The incidence of VTE in the intensive care unit is likely much higher than the general population. In one study DVT was found in 3.5% of those admitted to the intensive care unit (Miri et al. 2017).

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Spencer FA, Lessard D, Emery C, Reed G, Goldberg RJ. Venous thromboembolism in the outpatient setting. *Arch Intern Med*. 2007;167(14):1471–1475.

Keywords/Tags: Indication, epidemiology, DVT, risk factors

2. EXPLANATION

B. Repeat ultrasound in 1 week. Thrombosis in the greater saphenous vein is considered a superficial venous thrombosis. Superficial venous thrombosis and infrapopliteal DVT (such as calf vein thrombosis) have a lower risk of PE compared to proximal DVTs. Treatment of these thrombi with anticoagulation therapy is controversial and depends upon size of clot, elevation of D-dimer, proximity to proximal deep veins, patient's symptoms, and patient's risk factors for further thrombosis, as well as risk for anticoagulant complications (American College of Emergency Physicians et al. 2018; Kearon et al. 2016). One study showed that 4% of superficial thrombosis progressed to DVT (Dewar and Panpher 2010). Generally, if the thrombus is close to the junction of a deep or proximal vein or there are significant risk factors for thrombosis, there would be the inclination toward anticoagulation. If anticoagulation therapy is chosen, standard dosing and length of treatment for DVT applies, thus 12 months of anticoagulation would be excessive in a first time provoked DVT. For this reason, choice A is incorrect. Despite the differences in guideline recommendations, there is agreement that a repeat ultrasound is necessary to evaluate for clot progression of superficial venous thrombosis or infrapopliteal DVT not initially treated with anticoagulation (choice B).

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Keywords/Tags: Superficial thromboembolism, distal thromboembolism, DVT

3. EXPLANATION

B. Linear + Compression. The linear probe offers a higher frequency range that results in better resolution. This is the transducer of choice for this study as most veins are fairly superficial and therefore do not require the penetration of lower frequencies. Multiple types of linear probes are available to assess DVT (Figure 15.14) (Szabo 2013). There are many techniques that have been used to diagnose DVT using ultrasound including thrombus visualization, compression of vein, color flow, pulse wave Doppler, and respiratory phasicity (choices C, D). Of these, compression is the most accurate. Compared to a standard of contrast venography, compression only ultrasound was originally found to be 91% sensitive and 99% specific (Lensing et al. 1989). This was found to be superior to color Doppler alone (Lensing et al. 1997). A systematic review of multiple techniques showed that overall compression ultrasound was the most specific technique (97.8%), with a sensitivity for DVT of 90.3% (Goodacre et al. 2005). The addition of color and spectral Doppler (duplex, triplex) resulted in only modest improvements in sensitivities with decreased specificities (Table 15.1). However, respiratory phasicity can still be used as an

adjunct to compression in order to assess for patency between the extremity and the thorax. Likewise, augmentation can be used to assess for patency between the distal extremity and the vein being visualized. The phased array probe (choices A and C) has a phased arrangement of crystals and a low frequency range. It is commonly employed for cardiac and thoracic sonography.

Figure 15.14 **Different types of linear transducers.** The transducer to the left is a linear transducer with a longer foot print and would be ideal for looking at lower extremity deep vein thrombosis. The transducer in the middle is a linear transducer with a smaller foot print and could be used for IV access. The transducer to the right is called a hockey stick linear transducer and is used for assessing very superficial structures or pediatric patients.

Table 15.1 **TEST CHARACTERISTICS OF VARIOUS ULTRASOUND TECHNIQUES FOR THE DIAGNOSIS OF DEEP VENOUS THROMBOSIS**

ULTRASOUND TECHNIQUE	SENSITIVITY (%, FOR DEEP VEIN THROMBOSIS)	SPECIFICITY (%)
Compression only	90.3	97.8
Color Doppler only	81.7	92.7
Continuous wave Doppler	81.1	84.0
Duplex	92.2	94.0
Triplex	91.1	94.3

Adapted from: Goodacre S, Sampson F, Thomas S, van Beek E, Sutton A. Systematic review and meta-analysis of the diagnostic accuracy of ultrasonography for deep vein thrombosis. *BMC Med Imaging*. 2005;5:6.

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Szabo TL, Lewin PA. Ultrasound transducer selection in clinical imaging practice. *J Ultrasound Med*. 2013;32(4):573–582.

Keywords/Tags: Probe, DVT, acquisition, technique

4. EXPLANATION

B. Femoral vein. Focused lower extremity DVT ultrasound should focus on the 3 veins most likely to have VTE: the common femoral vein, the (superficial) femoral vein, and the popliteal vein. The superficial femoral vein is actually a deep vein and it has been renamed as the femoral vein to avoid confusion. The branch points of these vessels are the most common locations for DVTs to occur. The majority of first time DVTs occur in multiple veins. The most common combination was popliteal and femoral veins (42% of DVTs; Cogo 1993). The femoral vein and popliteal veins are the most common single veins involved. In 1 study, the femoral vein was involved in 74% and the popliteal vein in 73% of DVTs (Markel et al. 1992). The common femoral (choice D) was involved in 58% and the deep femoral (choice A) in 28%. Although DVT also occurs below the knee (choice C), above knee DVTs are 2–3 times more common (Bækgaard 2017).

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Keywords/Tags: DVT, anatomy, distribution

5. EXPLANATION

B. Mitral annular plane systolic excursion (MAPSE) of 1 cm. The findings of an enlarged RV (Figure 15.15a, Video 15.12), severe TR (Figure 15.15b, Video

15.13), and plethoric IVC (Figure 15.15c, Video 15.14) are all concerning for increased right heart pressures (Kurnicka et al. 2016; Goldhaber 2002). It is important to note that all of these findings can occur in both chronic and acute right heart pressure. However, in the appropriate clinical setting, this can be assumed to be right heart strain from an acute PE. The RV is normally smaller than the LV, usually approximately 60% of the size. When the RV size approaches that of the LV (choice A), that is abnormal and suggests right heart strain. The increased pressure will also cause increased TR (some trace TR can be normal) and a plethoric IVC (choices C and D). MAPSE is a seldom used measurement of left ventricular systolic function and therefore is not directly relevant to right heart strain (choice B). On the other hand, the tricuspid annular plane systolic excursion (TAPSE) is a measure of the right ventricular systolic function, and a measurement <16 mm is indicative of RV dysfunction.

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Keywords/Tags: Pulmonary embolism, right heart strain, tricuspid regurgitation, TAPSE

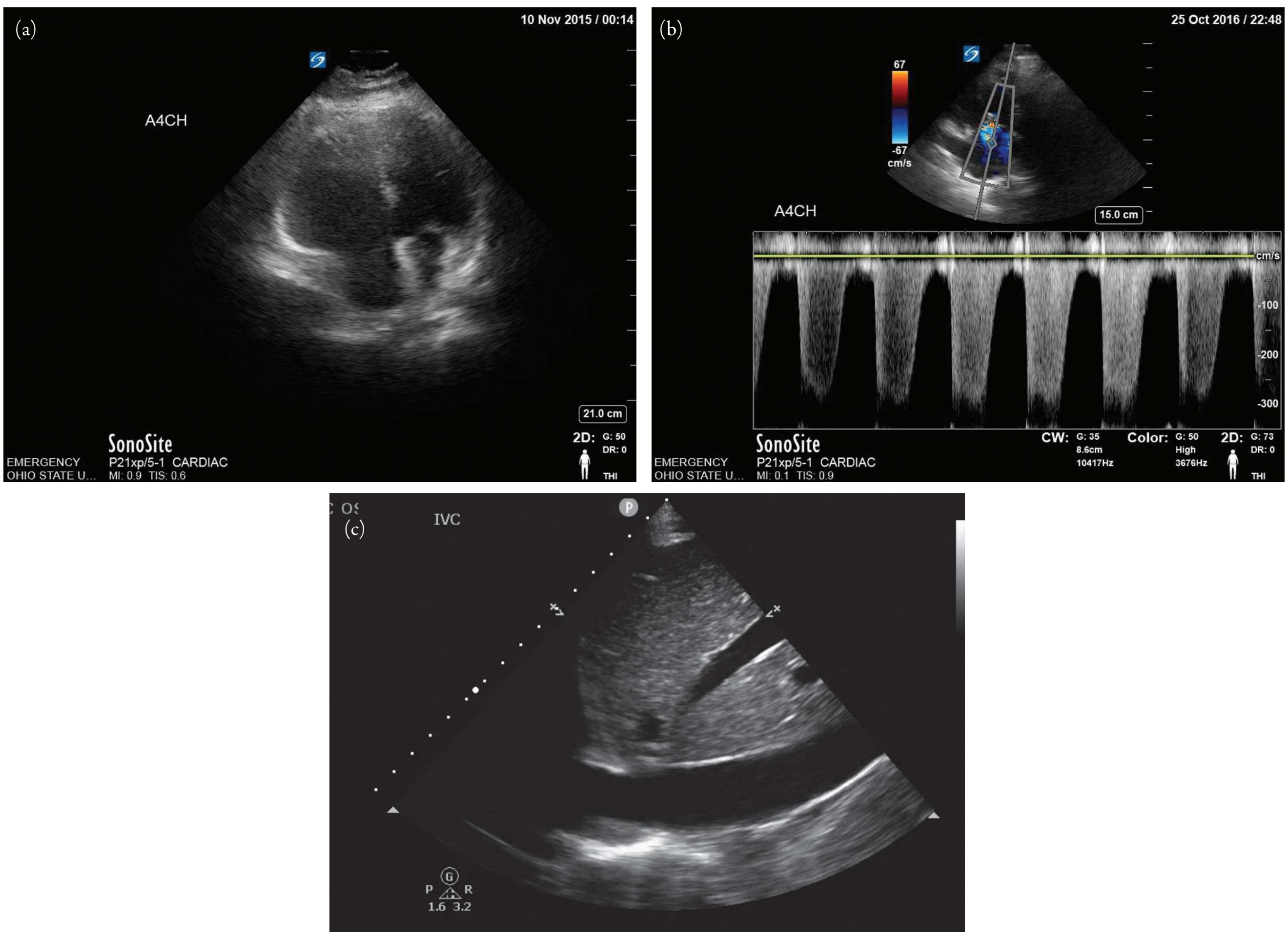

Figure 15.15 (a) **Enlarged right ventricle.** (b) **Tricuspid regurgitation.** (c) **Noncollapsible and dilated inferior vena cava.**

6. EXPLANATION

D. Greater saphenous vein. Deep veins in the lower extremity are defined as those enclosed by and deep to the muscular fascia. These veins include the common femoral vein, deep femoral (also known as the profunda femoris) vein, femoral vein (previously known as the superficial femoral vein), and the popliteal vein (choices A, B, C) (Black 2014). The popliteal vein becomes the femoral vein after ascending through the adductor magnus muscle. The femoral vein joins with the deep femoral vein and the greater saphenous to become the common femoral vein around the level of the inguinal ligament (Figure 15.16a). Therefore, scanning protocols should begin at the inguinal ligament to avoid missing proximal lower extremity DVTs. The femoral vein was previously referred to as the superficial femoral vein, but this is a misnomer because it is a deep vein (choice C; Caggiati et al. 2005). The greater saphenous vein is a superficial vein, but its junction with the common femoral vein can serve as a marker to the proximal starting point of lower extremity compression scanning (choice D; Figure 15.16b, Video 15.15). The deep femoral vein is seldom included in scanning protocols because isolated thrombus here is rare (Needleman et al. 2018).

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Needleman L, Cronan JJ, Lilly MP, et al. Ultrasound for lower extremity deep venous thrombosis: multidisciplinary recommendations from the Society of Radiologists in Ultrasound Consensus Conference. *Circulation*. 2018;137(14):1505–1515.

Keywords/Tags: Anatomy, femoral vein, venous anatomy, deep veins

7. EXPLANATION

C. Supine with frog leg positioning. Correct patient positioning is essential to any ultrasound examination. The patient should be undressed and appropriately draped so as to make the entire leg accessible. The patient should be supine, with the examined leg externally rotated (also known as frog leg position, Figure 15.17) (Necas 2010). This is to ensure blood pooling in the lower extremity veins for better distention and visualization. Studies have shown that this maneuver increases the size of the femoral vein (Read et al. 2012). It also allows an easy transition from the femoral vein to the popliteal vein examination. Having the patient upright may help with venous distention in the lower extremities but is not practical or ergonomic for a compression venous exam (choice A). Furthermore, when standing, a patient's pannus may compromise visualization of the proximal common femoral veins. Having the patient bend the knees restricts access to the inguinal femoral veins

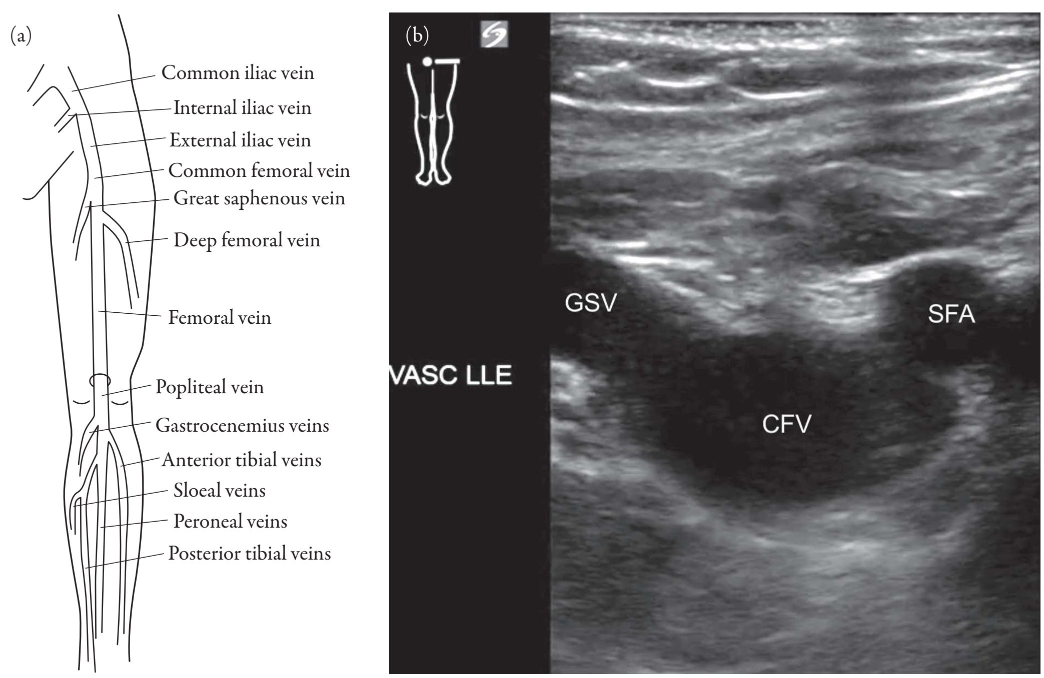

Figure 15.16 (a) **Lower extremity venous system.** Adapted from Figure 2 of Black CM. Anatomy and physiology of the lower-extremity deep and superficial veins. *Tech Vasc Interv Radiol.* 2014;17(2):68–73. doi:10.1053/j.tvir.2014.02.002. (b) **View of the common femoral vein (CFV) and the greater saphenous vein (GSV).**

Figure 15.17 **Frog leg positioning with leg externally rotated.**

(choice B). Having the patient in Trendelenburg could potentially decrease the size of the lower extremity veins and is not recommended (choice D). Placing a towel under the patient's thigh can help make the popliteal fossa more accessible and increase patient comfort.

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Read H, Holdgate A, Watkins S. Simple external rotation of the leg increases the size and accessibility of the femoral vein. *Emerg Med Australas*. 2012;24(4):408–413.

Keywords/Tags: DVT, positioning, femoral vein, acquisition, ergonomics

8. EXPLANATION

C. Greater saphenous vein. When assessing the popliteal vein for DVT, the knee should be slightly flexed and the probe on the posterior aspect of the knee in the popliteal fossa. It is important to assess the popliteal vein because this is commonly involved when there is a proximal thrombus. In one study 92% of proximal lower extremity DVT had popliteal involvement (Cogo et al. 1993). Up to 40% of these DVTs may be isolated below-knee DVTs (Markel et al. 1992). The deep veins of the calf should be interrogated from the proximal popliteal fossa caudally to its tributaries. As you scan the popliteal vein from proximal to distal, you will first note the branch of the anterior tibial veins (choice A). The popliteal continues and then splits into the posterior tibial and peroneal veins (Figure 15.16a) (choice B). The gastrocnemius and soleus veins also ultimately drain into the popliteal vein. It is important to ensure that you examine the vein proximal to this junction and interrogate through it as the trifurcation is a common location for thrombus. In contrast to the other veins, the greater saphenous vein (choice C) is part of the superficial venous system of the lower extremity. Although it begins in the foot, it drains in the common femoral vein at the saphenofemoral junction (Black 2014).

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Markel A, Manzo RA, Bergelin RO, Strandness DE. Pattern and distribution of thrombi in acute venous thrombosis. *Arch Surg*. 1992;127(3):305–309.

Keywords/Tags: Anatomy, lower extremity venous, trifurcation, popliteal vein, acquisition

9. EXPLANATION

D. Power Doppler. When performing a lower extremity venous ultrasound exam, it is important to assess the popliteal vein as this is frequently involved in cases of DVT (Cogo et al. 1993). Given the location of this vein within the popliteal fossa, it can be challenging to assess. Patient positioning is important. It is possible to assess the patient in a prone or lateral decubitus position, but this would require repositioning, which would be difficult in morbidly obese or critically ill patients. The popliteal vein should be interrogated with the knee slightly flexed (choice A) and the probe on the posterior aspect of the knee in the popliteal fossa (choice B). It is not feasible to image the popliteal veins anteriorly given its location deep to the leg bones. Generous use of augmentation and Valsalva (choice C) can increase the visibility and identification of the veins (Figure 15.18). Although power Doppler (choice D) can be used to find low-flow states, it is not generally considered a part of the venous duplex exam.

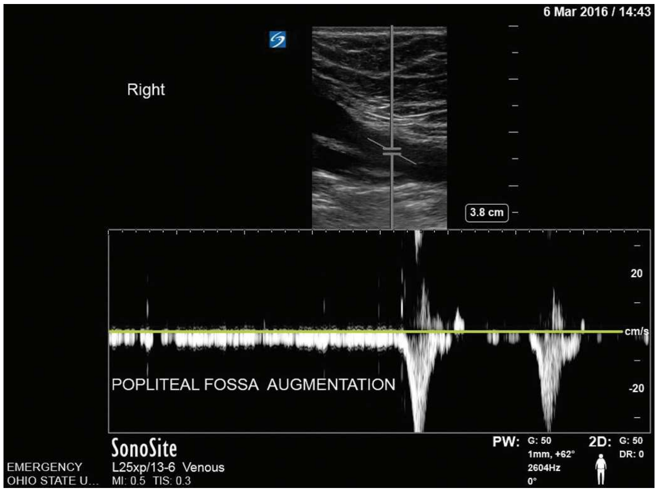

Figure 15.18 **Popliteal vein augmentation using pulsed-wave Doppler.**

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Keywords/Tags: Anatomy, lower extremity venous

10. EXPLANATION

B. Cellulitis. The differential diagnosis for DVT includes Baker's cyst, skin and soft tissue infection, lymphedema, peripheral edema, venous insufficiency, traumatic injuries, aneurysm, and pseudoaneurysm (Adhikari and Zeger 2015; Borgstede and Clagett 1992). Ultrasound can be used in the diagnosis of all of these pathologies. There is no vein visualized with findings suggestive of DVT in this clip (choice A). A baker's cyst would show an anechoic fluid collection with some echogenic material in the popliteal region (Figure 15.19a). Abscesses show an anechoic or hypoechoic fluid collection in the soft tissue without Doppler flow (choice C). Cellulitis is evidenced by increased edema in the soft tissue creating a "cobble-stone" appearance (choice B) (Adhikari and Blaivas 2012; Figure 15.3). Peripheral edema from volume overload can have a similar appearance so it

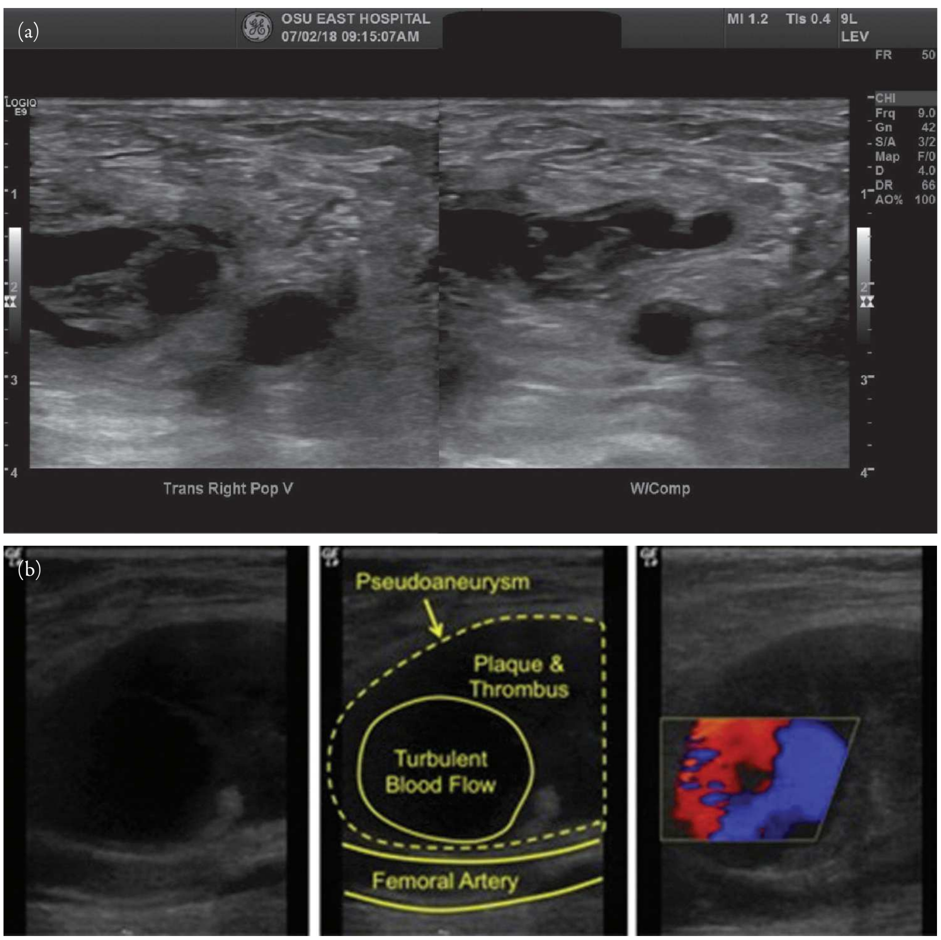

Figure 15.19 (a) Baker's cyst. (b) Pseudoaneurysm with "to and fro" waveform. Adapted from Figure 20 of Cook T, Nolting L, Barr C, Hunt P. Diagnostic ultrasonography for peripheral vascular emergencies. *Crit Care Clin*. 2014;30(2):185–206.

is important to consider the clinical exam and history to help distinguish. Aneurysms are dilations of the artery that can thrombose, embolize, or rupture. These should have an arterial waveform to differentiate from a vein. Pseudoaneurysms (choice D), which occur after percutaneous transarterial procedures or trauma, will show turbulent flow with a "to and fro" waveform at the neck of the pseudoaneurysm on Doppler (Figure 15.19b; Cook et al. 2014). Long bone fractures as well as soft tissue hematomas are also readily identified on ultrasound.

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Keywords/Tags: DVT, differential, Baker's cyst, abscess, musculoskeletal, pseudoaneurysm

11. EXPLANATION

C. Incorrect, we did not see the walls touch so we cannot make any conclusions. Compression is the most important aspect of the DVT evaluation. In order to meet criteria for a fully compressible vein, the walls must completely touch such that the vessel lumen is obliterated. This is referred to as vessel wall coaptation. Adequate compression occurs when either the vein is fully compressed or the adjacent artery starts to become compressed. This ensures that enough pressure is being applied such that noncoaptation of the vein is secondary to a thrombus and not because insufficient pressure is being applied. Compression has been shown to have a specificity of 97.8% in one meta-analysis (Goodacre et al. 2005). Coaptation of the vein is not seen in the image, likely because of inadequate compression (artery not compressed). Without adequate compression, the study cannot be interpreted as negative (choice A). Augmentation (choice B) and color Doppler can be a useful adjunct to compression but are not as accurate as compression in diagnosing DVT (Lensing et al. 1997). Regarding the accuracy of POCUS, there is variability in the literature. One study of 399 patients in the emergency department showed a sensitivity of 100% and specificity of 98.4%–99% compared to radiology performed duplex ultrasound (Magazzini et al. 2007). A second study found similar specificity but much lower sensitivity of 57.1% (Zitek et al. 2017). These discrepancies illustrate that the training and experience of the ultrasound operators may change the accuracy.

Learning Points:

- Make sure to apply adequate compression when evaluating for vein wall coaptation.
- Adequate compression occurs when either the walls of the vein completely touch each other or when the adjacent artery starts to become compressed.

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Zitek T, Baydoun J, Yepez S, Forred W, Slattery D. Mistakes and pitfalls associated with two-point compression ultrasound for deep vein thrombosis. *West J Emerg Med*. 2016;17(2):201–208.

Keywords/Tags: DVT, technique, acquisition, coaptation, accuracy, test characteristics

12. EXPLANATION

D. Disagree—these images are not adequate. The ultrasound performed by the initial physician shows no evidence of compression therefore DVT is not ruled out by compression. The vein does appear anechoic; however, this does not rule out DVT. Depending on the chronicity and nature of the clot, it can appear hypoechoic, hyperechoic, or anechoic (Brighton et al. 2007). Since acute clots can appear anechoic, visualization of a "patent lumen" does not rule out a DVT (choice C). The diagnosis of DVT should not rest on the visualization of a thrombus. This is why coaptation and additional adjunct maneuvers including augmentation are important in the diagnosis of DVT. Typically, acute clot is hypoechoic but it can be anechoic (choice A). As chronicity lengthens, the clot becomes more echogenic (Figure 15.20, Video 15.16) and the venous dilation decreases (Gornik and Sharma 2014); see Table 15.2. Eventually, recanalization and synechiae can develop along with collateral veins. It should be recognized that there is overlap in the findings of acute and chronic DVTs, and therefore the chronicity cannot always be determined (choice B). Studies have shown

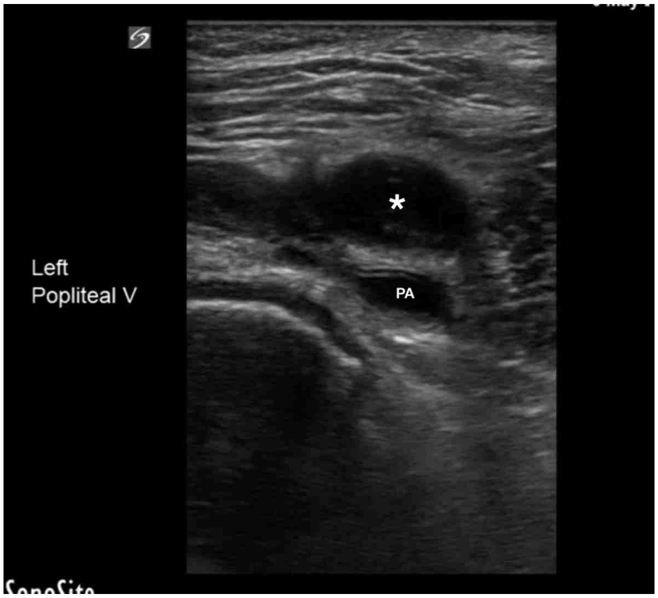

Figure 15.20 **Popliteal deep vein thrombosis (*) that appears hypoechoic.** PA = popliteal artery.

Table 15.2 **DISTINGUISHING FEATURES OF ACUTE VERSUS CHRONIC DVT**

FEATURES	ACUTE DVT	CHRONIC DVT
Compressibility	Slightly deformable	Noncompressible
Vein lumen diameter	Dilated	Contracted
Echogenicity	Hypoechoic	Hyperechoic
Collateralization	Generally absent	May be present
Venous valve function	Usually competent	Often incompetent

Note. DVT = deep vein thrombosis.

that there can be disagreement regarding the chronicity of a DVT (Linkins et al. 2006).

Learning Points: Thrombus on ultrasound can be anechoic (black), hypoechoic (less bright than surrounding structures), or hyperechoic (brighter than surrounding structures) depending on the chronicity of the clot.

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Keywords/Tags: Clot, ultrasound, diagnosis, echogenicity

13. EXPLANATION

D. This patient needs an MRI. Generally, the lower extremity ultrasound exam begins at the common femoral vessels. This means that the pelvic vessels such as the iliac veins are not directed evaluated (choice A). Isolated pelvic DVTs are rare and comprise only 2% of all DVTs. This rises to 10% to 12% in pregnancy (Bramante and Raio 2013), so choice C is incorrect. This means that the clinician must know when to suspect a pelvic DVT and what imaging is most useful in this case. Although empiric anticoagulation can be considered (choice B), there are risks with anticoagulation that may not be favorable, especially in the setting of pregnancy. Additional findings on lower extremity duplex that should increase concern for proximal DVT include turbulent blood flow, dilation, loss of respiratory phasicity, and more force required for compression (Bramante and Raio 2013). When suspicion is high and no DVT is found on 2-region exam, the next step is to pursue further imaging. This can be CT venography or MRI. CT venography is known to be accurate for diagnosing DVT with a sensitivity of 71% to 100% and a specificity of 93% to 100% (Bramante and Raio 2013; Karande et al. 2016). Disadvantages are the radiation and need for intravenous contrast. MRI, including magnetic resonance venography, can also be used to diagnose VTE. The sensitivity has been as high as 100%, and the American College of Radiology has recommended that this be next choice if venous ultrasound is nondiagnostic. In addition to high accuracy, MRI has the advantage of no radiation and noncontrast techniques. For this reason, this exam is the next step in the patient in this case (choice D). Disadvantages of MRI are the time and expense of the study. The advantages and disadvantages of the various methods of diagnosing DVT are discussed in Table 15.3.

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Keywords/Tags: Diagnostic, pelvic DVT, pregnancy, iliac

Table 15.3 **ADVANTAGES AND DISADVANTAGES OF VARIOUS MODALITIES USED FOR IMAGING DEEP VEIN THROMBOSIS**

MODALITY	ADVANTAGES	DISADVANTAGES
Contrast venogram	Gold standard Intervention can be performed in the same setting	Invasive Radiation Expertise required Intravenous contrast
Ultrasound	Readily available Quick Cost-effective Noninvasive No radiation No intravenous contrast Can be portable Can be used to estimate the age of thrombus	Operator dependent Difficult and less sensitive in patients with obesity, edema, tenderness, recent surgery, overlying bandages Difficult to directly image pelvic and abdominal veins
Computed tomography	Less operator dependent Better speed and spatial resolution Useful in obese patients Can evaluate pelvic and abdominal veins Can detect non-venous disease Can detect pulmonary thromboembolism	Pelvic radiation Intravenous contrast Artifacts from implants
Magnetic resonance imaging	No radiation Can evaluate pelvic and abdominal veins Can detect non-venous disease Non-contrast techniques available for patients with contrast allergy and renal failure Can be used to estimate the age of thrombus	Expensive Time consuming Cannot be performed in patients with MR incompatible implants Requires expertise for interpretation
Scintigraphy	Can be used to estimate the age of the thrombus May be useful in differentiating bland from tumor thrombus Limited availability	Limited data available Expensive Radiation

Adapted from Table 15.1, Karande GY, Hedgire SS, Sanchez Y, et al. Advanced imaging in acute and chronic deep vein thrombosis. *Cardiovasc Diagn Ther*. 2016;6(6):493–507. doi:10.21037/cdt.2016.12.06.

14. EXPLANATION

D. Reflux in the common femoral vein. As previously discussed, it can be difficult to directly visualize the proximal vessels such as the iliac veins or the IVC. Furthermore, given the depth at which these vessels are located, even when visualized, compression is not feasible. However, indirect evidence of proximal DVT can be seen during lower extremity duplex. These findings include turbulent blood flow, dilation, more force required for compression, and loss of phasicity (also known as monophasicity) (Bramante and Raio 2012). Reflux in distal veins is not dependent on proximal obstruction but rather intrinsic valvular disease of the interrogated vein (choice D). Respiratory phasicity in particular is commonly assessed during venous Doppler and can be helpful for patients with increased suspicion for a proximal DVT. In normal physiology, inspiration leads to decreased intrathoracic pressure, which causes changes in the blood flow that can be seen spectral Doppler (Figure 15.21a). In the lower extremity vessels, the intraabdominal pressure is generally increased during inspiration which can also affect the Doppler flow. The absence of this phasicity (Figure 15.21b) generally indicates an obstruction between the vessel being interrogated and the thorax. It is unclear how sensitive this finding is, but in one study 40% of monophasic waveforms were related to proximal thrombus (Lin et al. 2007). Other causes of monophasic waveforms were lymph nodes, tumors, and hematoma compression the veins. Therefore, the presence of a monophasic waveform should encourage the practitioner to further evaluate for proximal thrombus; however, normal phasicity does not rule out a proximal thrombus. This is because a nonobstructing thrombus may not necessarily alter the respiratory changes in blood flow.

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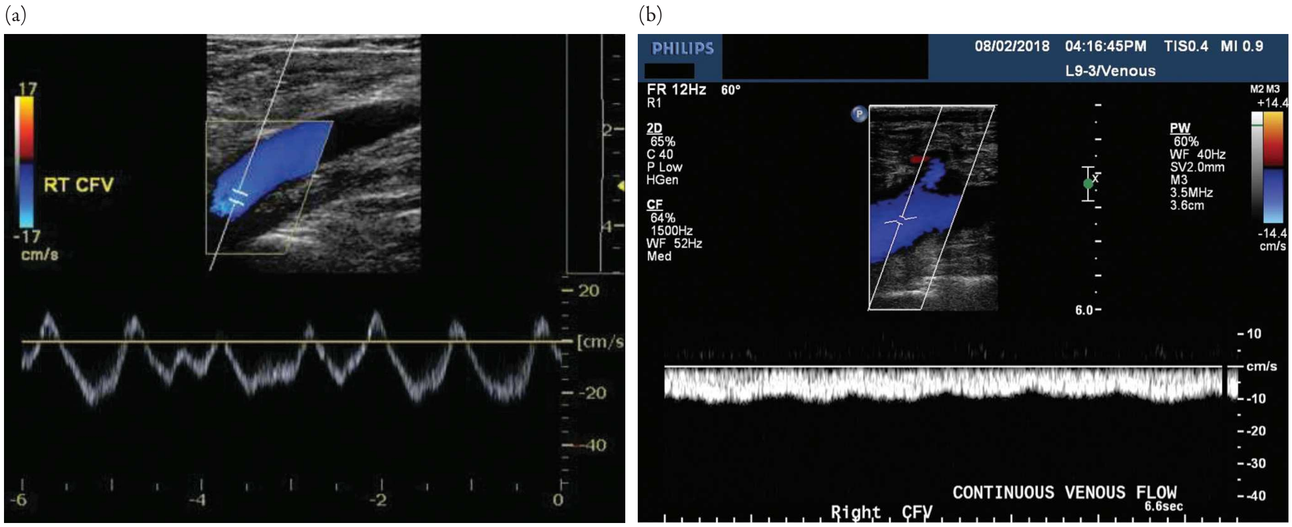

Figure 15.21 (a) **Spectral Doppler tracing of the right common femoral vein in a patient with normal phasic variation.** Adapted from Figure 1a of Lin EP, Bhatt S, Rubens D, Dogra VS. The importance of monophasic Doppler waveforms in the common femoral vein: a retrospective study. *J Ultrasound Med*. 2007;26(7):885–891. (b) **Spectral Doppler tracing showing a monophasic waveform in the common femoral vein.** Adapted from Figure 1b of Lin EP, Bhatt S, Rubens D, Dogra VS. The importance of monophasic Doppler waveforms in the common femoral vein: a retrospective study. *J Ultrasound Med*. 2007;26(7):885–891.

Lin EP, Bhatt S, Rubens D, Dogra VS. The importance of monophasic Doppler waveforms in the common femoral vein: a retrospective study. *J Ultrasound Med*. 2007;26(7):885–891.

Keywords/Tags: Diagnostic, pelvic DVT, iliac DVT, IVC thrombus

15. EXPLANATION

B. Thrombolysis with iliac vein stenting and 3 months of anticoagulation. The patient in this vignette has iliac vein compression syndrome, also known as May Thurner syndrome (MTS). MTS is the compression and eventual thrombosis of the left common iliac vein by the right common iliac artery (Brinegar 2015); see Figure 15.22. This mechanism is implicated in 50% to 60% of left-sided iliofemoral DVTs. It often affects young healthy women. Other causes of thrombosis should be ruled out prior to diagnosing MTS. In many cases, this disease should be treated differently than other types of DVT. These patients benefit from thrombolysis and stenting of residual venous disease (Carroll and Moll 2016). This therapy offers good long-term benefit in terms of recurrence and post-thrombotic symptoms. While the presence of DVT in the setting of May Thurner anatomy is sufficient to initiate treatment (choice D), intraprocedural intravascular ultrasound is the best way to assess for adequacy of treatment (Brinegar 2015). Anticoagulation alone incurs a high risk of post-thrombotic disease, and thrombolysis without stenting (choice C) of residual chronic venous obstruction in the left iliac vein will have a higher recurrence rate. Choice A would be appropriate if the patient had a provoked DVT without evidence of MTS.

Learning Points: Have a high suspicion for MTS in patients with iliofemoral DVT. Treatment is iliac vein stenting and antiacoagulation.

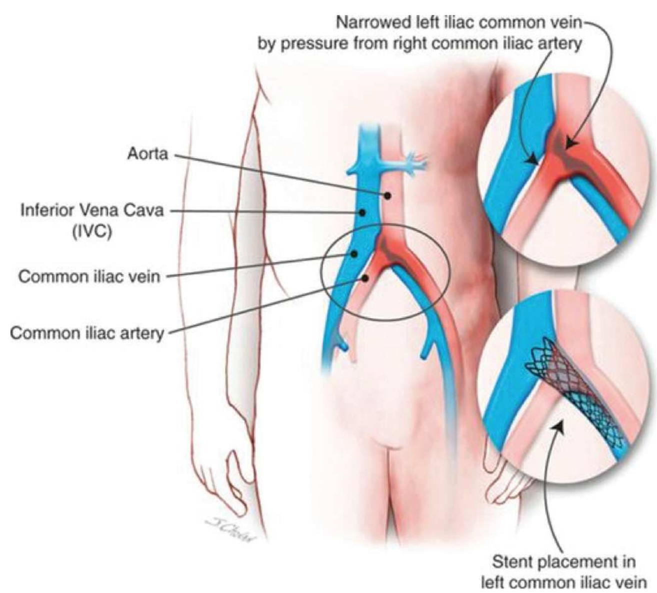

Figure 15.22 **May Thurner syndrome (MTS) resulting from compression of the left common iliac vein by the right common iliac artery.** Treatment of MTS involves placing a stent in the left common iliac vein. Adapted from Figure 2, Carroll S, Moll S. Inferior Vena Cava Filters, May-Thurner Syndrome, and Vein Stents. *Circulation*. 2016;133(6):e383–e387. doi:10.1161/CIRCULATIONAHA.115.019944.

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Keywords/Tags: May Thurner syndrome, thrombolysis, venous stents

16. EXPLANATION

A. <10%. There are many different ultrasound protocols for lower extremity DVTs (Figure 15.23). The 2-point exam is a protocol that assesses only the common femoral vein and the popliteal vein. This allows for a relatively fast examination of 2 very commonly affected areas. It was previously thought to be nearly equivalent to whole leg sonography (Bernardi et al. 2008). However, there is now evidence that this will miss a significant amount of DVTs. One retrospective study showed 6.3% of DVTs in the lower extremity would be missed as a result of being located in the femoral vein or deep femoral vein (Zitek et al. 2016). The majority of these cases were located in the femoral vein.

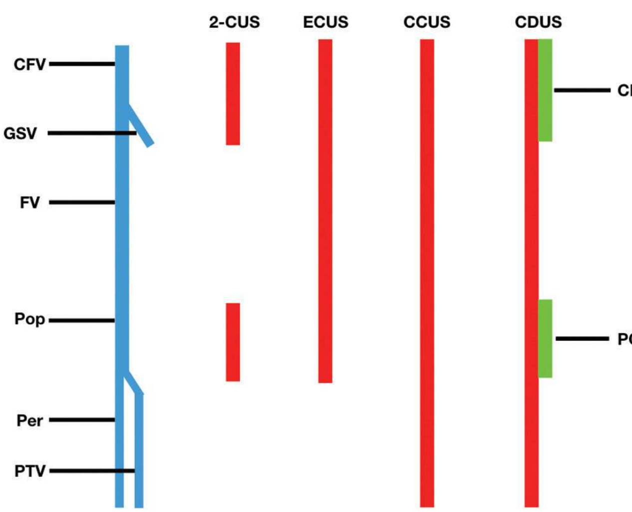

Figure 15.23 **Difference between venous ultrasound protocols for lower extremity deep vein thrombosis.** 2-CUS (2-region compression ultrasound) indicates compression ultrasound including the femoral veins 1 to 2 cm above and below the saphenofemoral junction and the popliteal veins up to the calf veins confluence; ECUS (extended compression ultrasound), the compression ultrasound from common femoral vein through the popliteal vein up to the calf veins confluence; CCUS (complete compression ultrasound), compression ultrasound from common femoral vein to the ankle; and CDUS (complete duplex ultrasound), compression ultra- sound from the common femoral vein to the ankle (evaluating the posterior tibial and peroneal veins in the calf), color and spectral Doppler of the common femoral (or iliac veins) on both sides, color and spectral Doppler of the popliteal vein on the symptomatic side. CFV = common femoral vein; GSV = greater saphenous vein; FV = femoral vein; POP = popliteal vein; Per = peroneal vein; PTV = posterior tibial vein.

A prospective study using a 2-point compression protocol in the emergency department only had a sensitivity of 57.1% compared to radiology performed ultrasound (Adhikari et al. 2015). The Society of Radiologists in Ultrasound released a consensus statement recommending that in point-of-care DVT evaluations, an extended compression protocol including the deep venous system from the common femoral to the popliteal vein should be used instead of a more limited 2-region compression (Needleman et al. 2018). Ultimately, the point-of-care protocol a practitioner chooses may depend on local practice patterns and the ability for follow-up and repeat comprehensive imaging; however, the evidence shows that extended protocols should increase sensitivity for DVT.

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Zitek T, Baydoun J, Yepez S, Forred W, Slattery D. Mistakes and pitfalls associated with two-point compression ultrasound for deep vein thrombosis. *West J Emerg Med*. 2016;17(2):201–208.

Keywords/Tags: DVT, accuracy, diagnosis, femoral veins

17. EXPLANATION

C. Once anticoagulated, the risk of PE is fairly low. The ultrasound shows a popliteal vein DVT. Pulmonary emboli are a known complication of DVT and the prevention of PE is a primary reason for treatment with anticoagulation. It is estimated that PE will occur in 50% of DVTs (Tapson 2008). This is why choice B is incorrect. With anticoagulation, the risk of recurrent VTE is 5% to 10% during the first year after diagnosis (choice C). Many PEs after a DVT are asymptomatic and termed "silent PEs." One meta-analysis estimated that this occurs in 32% of those diagnosed with DVT (Stein et al. 2010). Importantly, the authors found that those diagnosed with a silent PE had an increased risk of having a symptomatic PE (choice A). Conversely, up to 79% of those diagnosed with PE will already have a concurrent DVT at the time of diagnosis (Tapson 2008). There is evidence that, among those with PE, having a concurrent DVT increases the chance of poor outcomes (Lee et al. 2016). Despite this fact, guidelines suggest that IVC filters be reserved primarily for cases in which anticoagulation is

contraindicated (Kearon et al. 2016). This may be due to an increased incidence of DVT seen with IVC filters.

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Keywords/Tags: DVT, management, pulmonary embolism, IVC filter

18. EXPLANATION

B. Augmentation. The video clip illustrates augmentation on color Doppler. Augmentation is a method that can be used to assess for a complete obstruction distal to the point of scanning. To perform this maneuver, compress or squeeze (or have an assistant squeeze) the patient's calf while scanning in a proximal area of the same extremity (Lockhart et al. 2005). In a normal vein, there will be an increase in velocity seen on color or spectral Doppler (Figure 15.24). This confirms that there is not a complete obstruction between the area that was compressed and the transducer. Comparison to the asymptomatic extremity for symmetrical augmentation may be useful. The lack of augmentation suggests an occlusion by thrombus. However, normal augmentation does not rule out the possibility of a nonocclusive DVT. In fact, a study of 1,980 patients found that augmentation was useful 3.3% of the time (Lockhart et al. 2005). The investigators recommended that this maneuver not be routine but be reserved as an adjunctive diagnostic method. Another study examined the accuracy of a single point augmentation-only DVT examination. They found a sensitivity and specificity of 82% and 89%, respectively (McQueen et al. 2009). Although augmentation has limited evidence supporting its use, it is still commonly employed in comprehensive examinations (Needleman et al. 2018).

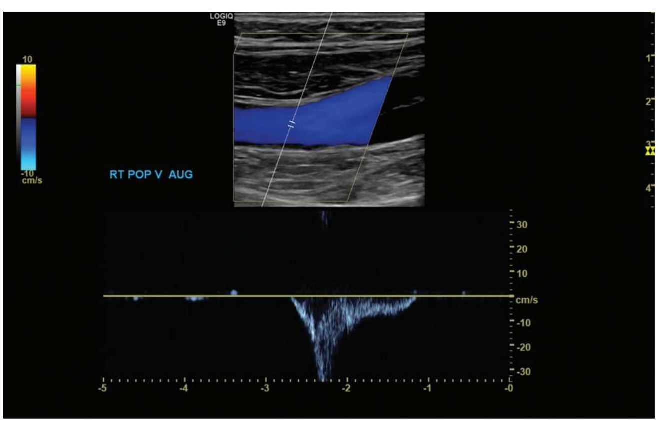

Figure 15.24 **Popliteal vein augmentation visualized with spectral Doppler.**

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Keywords/Tags: Acquisition, augmentation, physics, technique, DVT

19. EXPLANATION

B. It is better not to as there is a risk of clot mobilization. Though extremely rare, propagation of a DVT by direct compression causing PE has been reported. The theoretical mechanism is that the compression of a thrombus can lead to some or all of it embolizing. Unfortunately, this is a very difficult phenomenon to study. Unless this event is directly visualized, it is hard to prove a causal relationship between compression and PE. This relationship is confounded by the fact that a proportion of DVTs will lead to PE even without excessive compression. One systematic review of the topic screened over 3,600 articles and found 8 case reports in which the ultrasound was implicated in causing a PE (Mehdipoor et al. 2016). We do not know the true incidence of this event due to the difficulty in establishing causal relationship and possible underreporting. Although the risk appears minimal, it is best to avoid excessive force with compression or unnecessary repeat ultrasound exams, unless otherwise indicated (choice A). Patient comfort (choice D) is a further concern although this is not the only concern. There is no evidence that repeated ultrasound is therapeutic for DVT (choice C).

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Keywords/Tags: Risk, acquisition, iatrogenic embolus, compression

20. EXPLANATION

D. Venous ultrasound. This pregnant patient presents with signs of both PE and DVT. Making this diagnosis in pregnancy presents many unique challenges. The symptoms of DVT and PE have overlap with normal pregnancy-related physiologic changes, many pretest probability tools do not apply in pregnancy, and, in determining diagnostics, there is increased concern for maternal and fetal radiation exposure (McLean and James 2018). With regard to the latter concern, in a pregnant patient with concern for PE and signs of a DVT, an ultrasound to assess for DVT (choice D) is the first choice for imaging. In this case, if positive, treatment with anticoagulation can begin with the presumptive diagnosis of a concurrent PE. Low molecular weight heparin or unfractionated heparin are usually recommended (James et al. 2011). See Figure 15.25 for an example algorithm for suspected DVT or PE in pregnancy. In patients without signs of DVT or a negative venous ultrasound, there is still debate regarding the superiority of a ventilation/perfusion scan versus a CT pulmonary angiography study. Ventilation perfusion studies (which can also be done without the ventilation study) are sometimes favored due to less radiation exposure to the mother; however, a CT may have slightly less radiation to the fetus (Leung et al. 2011). The American Thoracic Society and Society of Thoracic Radiology recommend V/Q in the case of a normal chest X-ray but CT angiography if the chest X-ray is abnormal. MRI is not currently used in the diagnosis of PE due to concern for the effects of gadolinium on the fetus (choice C). Even in the nonpregnant patient, diagnosing DVT in a patient with suspected PE is highly predictive of the presence of PE. In 1 study it was 87.6% specific with a likelihood ratio of 21.7 (Nazerian et al. 2014).

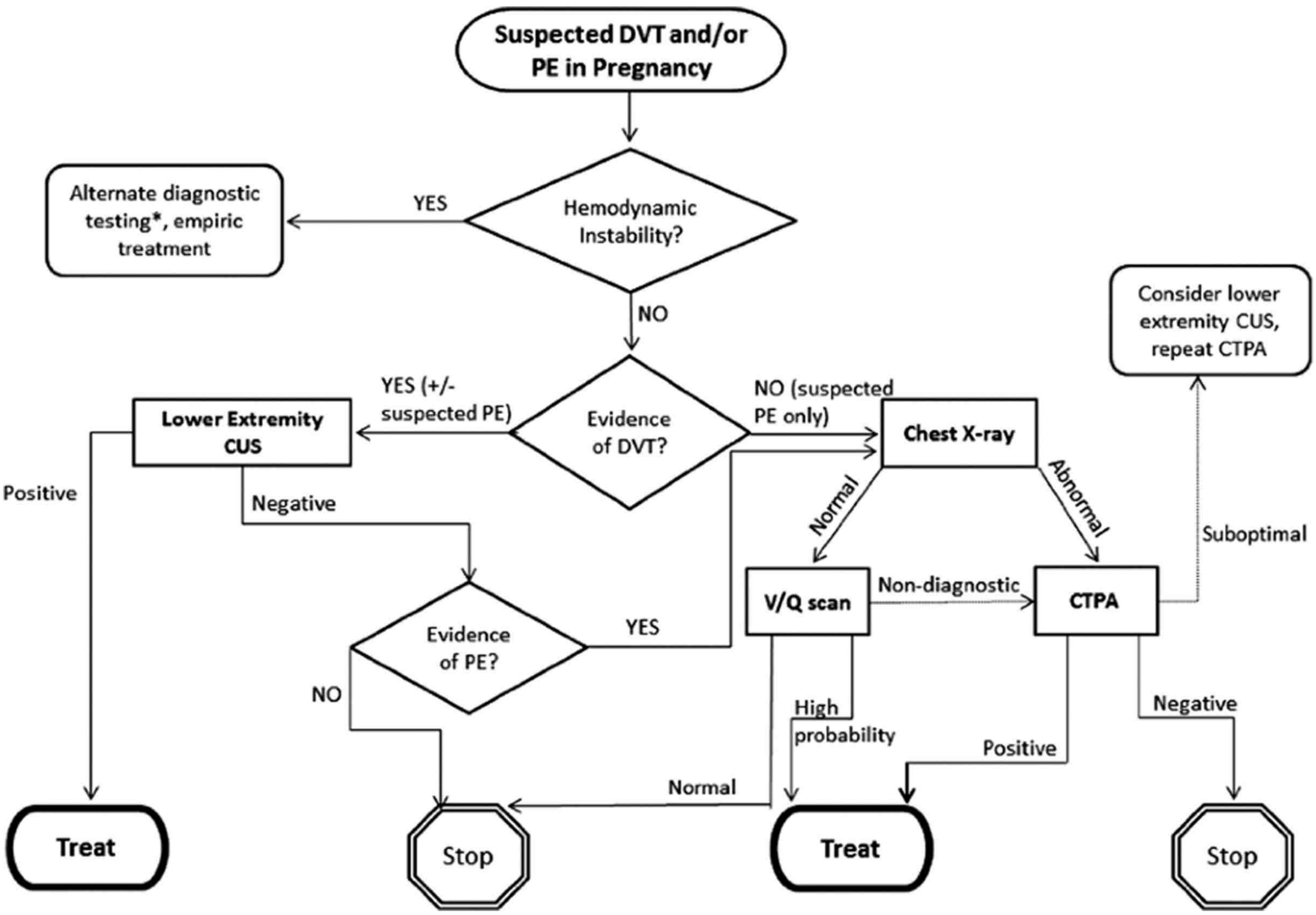

Figure 15.25 **Algorithm for evaluation of suspected deep vein thrombosis (DVT) and/or pulmonary embolism (PE) in pregnancy.**
CUS = compression duplex ultrasonography; CTPA = computed tomographic pulmonary angiography; V/Q = ventilation/perfusion scan. Adapted from Figure 1 of McLean KC, James AH. Diagnosis and management of VTE in pregnancy. *Clin Obstet Gynecol.* 2018;61(2):206–218. doi:10.1097/GRF.0000000000000354.

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Keywords/Tags: Diagnostic, DVT, PE, pregnancy

21. EXPLANATION

D. Assess for an infectious etiology. In the patient presented in this vignette, both DVT and a skin and soft tissue infection would be on the differential. The ultrasound image depicts an inguinal lymph node seen in the groin. Lymph nodes are commonly visualized in the inguinal region while evaluating the femoral veins. These can appear as hypoechoic circular structures that mimic the appearance of a DVT (Białek and Jakubowski 2017). Color Doppler often shows flow in the hilum of the lymph node (Figure 15.8b, Video 15.8). In contrast to a DVT, lymph nodes are discrete structures. Scanning proximally and distally can confirm they are not connected to a vein. They are also generally more superficial than the deep veins being evaluated. A knowledge of anatomy including the common location for lymph nodes is helpful in anticipating this finding. Unfortunately, lymph nodes are still a cause for false positives during point of care DVT scans (Zitek et al. 2016). In the setting of an enlarged lymph node and a swollen red leg, the next appropriate step would be to assess for a possible infectious etiology (choice D). Choice C, incision and drainage, would be appropriate if the ultrasound showed a superficial abscess. Vascular consultation (choice B) would be appropriate if the patient had evidence of a vascular emergency, which this patient does not.

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Keywords/Tags: Management, lymph nodes, DVT, differential

22. EXPLANATION

D. All of the above. It is intuitive and well demonstrated that more severe acute pulmonary emboli can cause right heart dysfunction. This occurs due to the sudden increases in right-sided pressures from the thrombus in the pulmonary arteries. This is an important finding because it has implications for prognosis and management. Echocardiography is the diagnostic of choice for determining the presence or absence of signs of this dysfunction (Weekes et al. 2016). Findings of right heart strain include right ventricular enlargement, right ventricular hypokinesis, interventricular septal flattening or bowing, TR, pulmonary hypertension, McConnell's sign, right heart thrombus, low TAPSE, and a plethoric IVC. The RV should be approximately two-thirds of the LV, so when it approaches the same size, it is likely enlarged (Figure 15.26a, Video 15.17). Likewise, the

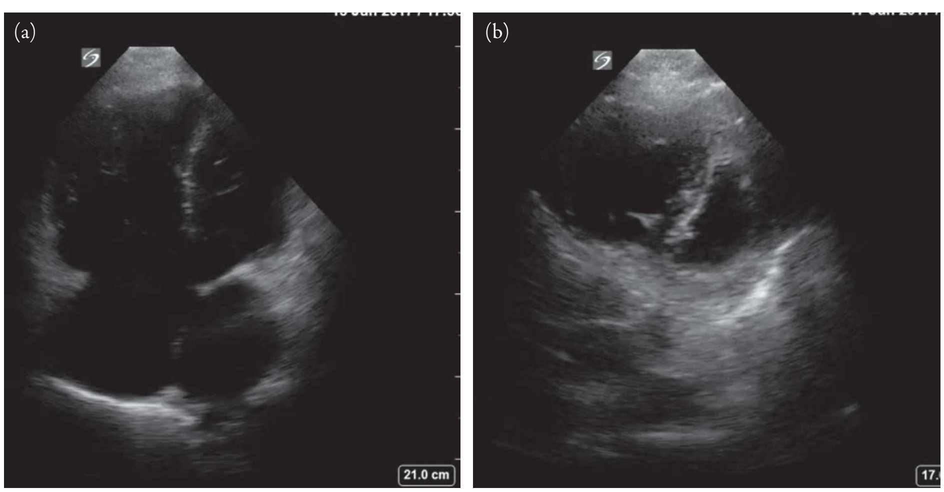

Figure 15.26 (a) **Apical 4-chamber view showing right ventricular dilation with right ventricle larger than left ventricle.** (b) **Parasternal short axis view showing dilated right ventricle with bowing of the interventricular septum into the left ventricle.** This is also known as the "D" sign since the shape of the left ventricle looks like a "D" shape.

Table 15.4 **ECHOCARDIOGRAPHIC FINDINGS OF RIGHT HEART STRAIN**

ECHOCARDIOGRAPHIC FINDING OF RIGHT HEART STRAIN	ABNORMAL VALUE
End-diastolic diameter	**Base ≥42 mm Mid-level >35 mm**
Tricuspid Regurgitation	**>2.8–2.9 m/s**
Tricuspid annular plane systolic excursion	**<1.6 cm**
Low collapsibility of inferior vena cava (high right atrial pressure)	**>2.1 cm with <50% collapsibility**

Based on values from American Society of Echocardiography (Rudski et al. 2010).

interventricular septum normally bows toward the lower pressure RV. Reversal of this normal findings with bowing toward the left is concerning for increased right-sided pressures (Figure 15.26b, Video 15.18). Multiple findings of right heart strain can be seen on echocardiography (see Table 15.4). Other tests such as electrocardiogram, CT, and serum markers can also assist in making this diagnosis. One study by Weekes et al. specifically looked at the accuracy of POCUS performed by emergency physicians compared to a comprehensive echocardiography study. They found that a focused echocardiography exam assessing for RV enlargement, reduced systolic function, and septal bowing was 100% sensitive and 99% specific for right heart strain. This was more accurate than both serum and CT markers of right heart strain. Table 15.5 shows the accuracies of these modalities found in this study. It is important to note that these findings of right heart strain should not be used as the sole diagnostic test for the diagnosis of PE. Because not all PEs will develop right heart strain, echo lacks sufficient sensitivity to rule out the diagnosis (Fields et al. 2017). On the other hand, many of these findings are fairly specific. Therefore, point-of-care echo has been used to diagnose a submassive or massive PE and initiate treatment immediately (Myers et al. 2017).

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Weekes AJ, Thacker G, Troha D, et al. Diagnostic accuracy of right ventricular dysfunction markers in normotensive emergency department patients with acute pulmonary embolism. *Ann Emerg Med*. 2016;68(3):277–291.

Keywords/Tags: Right heart strain, PE, stratification, diagnosis

23. EXPLANATION

C. This patient has a poor prognosis. The measurement seen in the image is a TAPSE. The TAPSE is a measure of right heart systolic function. It measures the distance that the tricuspid moves during systole by using M-mode in an apical 4-chamber view (Rudski et al. 2010). In obtaining this measurement, it is key that the M-mode cursor aligns with the plane of motion of the tricuspid annulus so as to obtain an accurate measurement (Figure 15.27a, Video 15.19) (Figure 15.27b). Oblique planes during the apical 4-chamber view will also inaccurately measure the TAPSE. A TAPSE less than 16 mm is considered low and reflects poor right ventricular systolic function. In the setting of suspected acute PE, this can be an indicator of right heart

Table 15.5 **ACCURACY OF DIAGNOSTIC TESTS FOR RIGHT VENTRICULAR DYSFUNCTION COMPARED TO COMPREHENSIVE ECHOCARDIOGRAPHY**

DIAGNOSTIC TEST	SENSITIVITY (%)	SPECIFICITY (%)	LIKELIHOOD RATIO	LIKELIHOOD RATIO
Goal-directed echocardiography (GDE)	**100**	**99**	**90**	**0**
Computer tomography	**91**	**79**	**4.3**	**0.11**
Troponin	**62**	**93**	**9.2**	**0.41**
Brain-type natriuretic peptide (BNP)	**88**	**68**	**2.8**	**0.17**

Adapted from Weekes AJ, Thacker G, Troha D, et al. Diagnostic accuracy of right ventricular dysfunction markers in normotensive emergency department patients with acute pulmonary embolism. *Ann Emerg Med*. 2016;68(3):277–291.

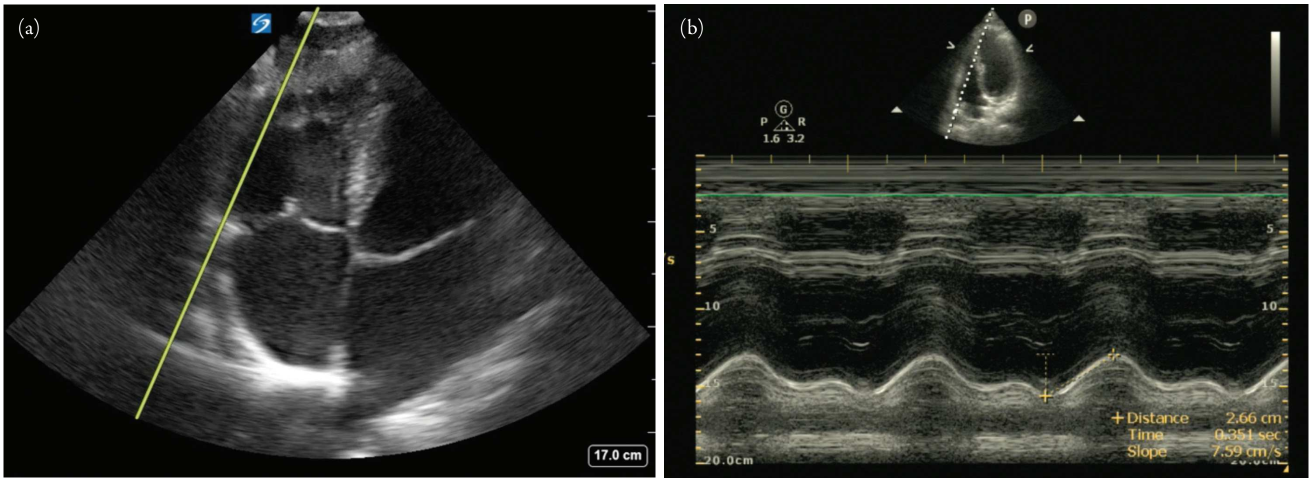

Figure 15.27 (a) **Correct M-mode cursor placement for measurement of the tricuspid annular plane systolic excursion (TAPSE).** (b) **Correct use of caliper positions to measure the tricuspid annular plane systolic excursion (TAPSE).**

strain. TAPSE, in particular, has been shown to have great prognostic value. A low TAPSE in normotensive patients with PE is an independent risk factor for worse outcomes (choice C). One study showed a TAPSE ≤ 16 mm had worse echocardiographic right heart function and was predictive of mortality from PE with a hazard ratio of 4.4 (Lobo et al. 2014). Another study in a smaller population showed a hazard ratio of 26.2 for a TAPSE ≤15 mm (Paczyńska et al. 2016). This prognostic information can be valuable given the spectrum of illness of patients who are normotensive and suffering from PE. It may assist in decisions regarding therapies or level of care. As with other markers of right heart strain on echo, TAPSE is not sensitive enough to exclude PE (Daley et al. 2016). There is no pericardial effusion and no evidence of tamponade, so choice A is incorrect. TAPSE is a measure of right hear function, not left heart function, so choice B is incorrect. Massive PE will include hemodynamic instability, which this patient does not have, thus choice D is incorrect.

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Keywords/Tags: TAPSE, PE, risk stratification, diagnosis, management

24. EXPLANATION

C. Reassurance and nonsteroidal anti-inflammatory drugs (NSAIDs). The images shown depict a Baker's cyst. Baker's cysts are fluid-filled structures that are a continuation of the synovial capsule of the knee. With inflammation, these cause pain and swelling and can mimic the clinical presentation of a DVT. Cysts are found in up to 15% of patients who are receiving lower extremity venous duplex ultrasounds (Adhikari and Zeger 2015). Baker's cysts are well-defined cysts with clear borders and can have internal echoes. They have a "neck" at their deepest extent, extending into the joint space between the semimembranosus tendon and the medial head of the gastrocnemius (Jamadar et al. 2002). It typically will appear crescent shaped. Identification of a fluid-filled structure at the posteromedial knee is suggestive of a Baker's cyst, but identification of the "neck" between the tendons is necessary for a definitive diagnosis. Baker's cysts are generally treated symptomatically with NSAIDs, although some advocate for drainage of the knee joint for improved relief. In contrast to a DVT (choice A), Baker's cysts do not track superiorly and inferiorly like a vein. The differential for a cystic structure would also include parameniscal cysts and liquefied hematoma. A soft tissue abscess (choice B) is on the differential as well although knowledge of the typical anatomic location and appearance of a Baker's cyst can help make the diagnosis in this case. A pseudoaneurysm or aneurysm of the popliteal artery would make consultation with vascular surgery (choice D) an appropriate choice. These vascular problems

would appear in the location of the popliteal artery (deep to the vein when scanning from popliteal fossa) and exhibit flow on color Doppler, which was absent on the images in this case (Cook et al. 2014).

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Keywords/Tags: DVT, diagnosis, Differential, Bakers cyst, aneurysm, vascular

25. EXPLANATION

C. RV wall thickness. This patient presents with an interesting diagnostic dilemma. Right heart dysfunction in the setting of an acute PE is helpful in determining therapy options and prognosis. However, patients can have very similar echocardiographic findings cause by chronic processes such a primary or secondary pulmonary hypertension. Findings such as RV enlargement (choice D), septal bowing, hypokinesis, and a low TAPSE (choice A) can occur in both acute and chronic pulmonary hypertension. When patients with chronic pulmonary hypertension get an acute PE, it can be challenging to determine if the observed findings are due to the chronic disease or the acute insult to the right heart. Overall, this determination may not be possible within the scope of focused echocardiography unless a thrombus in transit is visualized. There are, however, a few more advanced measurements that can be helpful (Watts et al. 2010). The abrupt vascular occlusion caused by a PE can lead to immediate dilation of the RV. In more chronic forms of pulmonary hypertension, the RV will often hypertrophy prior to dilating (Rudski et al. 2010). Right ventricular wall thickness (choice C) can be measured at end-diastole in a subcostal window in M-mode or B-mode (Figure 15.28a). The measurement should be at the level of the anterior tricuspid leaflet. A value >0.5 cm is considered abnormal and can suggest right pressure overload (Rudski et al. 2010). Since hypertrophy does not occur instantaneously, the presence of RV hypertrophy can suggest the presence of chronic pulmonary hypertension. The 60/60 rule is another finding designed to differentiate acute and chronic causes of high right-sided pressures. The 60/60 sign refers to 2 measurements: first, a pulmonary acceleration time ≤60 ms and second a tricuspid gradient not >60 mmHg (Figure 15.28b; Kurzyna 2002). In order to calculate the pulmonary acceleration time, a parasternal short axis view is obtained showing the right ventricular outflow tract (Figure 15.28c, Video 15.20). The pulse wave Doppler sampling gate cursor is placed at the right ventricular outflow tract (Figure 15.28d) and the pulmonary acceleration time is measured (Figure 15.28e). To measure the tricuspid gradient, initially place color Doppler to find location of TR and then use continuous wave Doppler to measure Tricuspid gradient (Figure 15.28f). If both of criteria for the 60/60 sign are met, then it is fairly specific for acute PE. See Table 15.6 for more details on how to obtain these measurements. This sign can be technically challenging to obtain. Studies have shown reasonable specificity but poor sensitivity (Fields et al. 2017). McConnell's sign (choice B) describes the finding of a hyperkinetic RV apex with hypokinesia of the right free wall. This was originally described as nearly pathognomonic for acute PE, but since then has been found to be present in right ventricular infarction as well (Casazza et al. 2005). It is important to note in any of these signs that while the findings of acute signs of right heart strain may suggest an acute PE, the findings of chronic right heart strain certainly do not exclude PE.

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Keywords/Tags: Diagnosis, RV strain, PE, acute, chronic, pulmonary hypertension, 60/60 sign.

26. EXPLANATION

A. This is a sign of right heart dysfunction. The ultrasound shows McConnell's sign. This sign is defined as a hypokinetic or akinetic right ventricular free wall but with preservation of the function of the apex of the RV This is a sign of poor right ventricular function (choice A). It

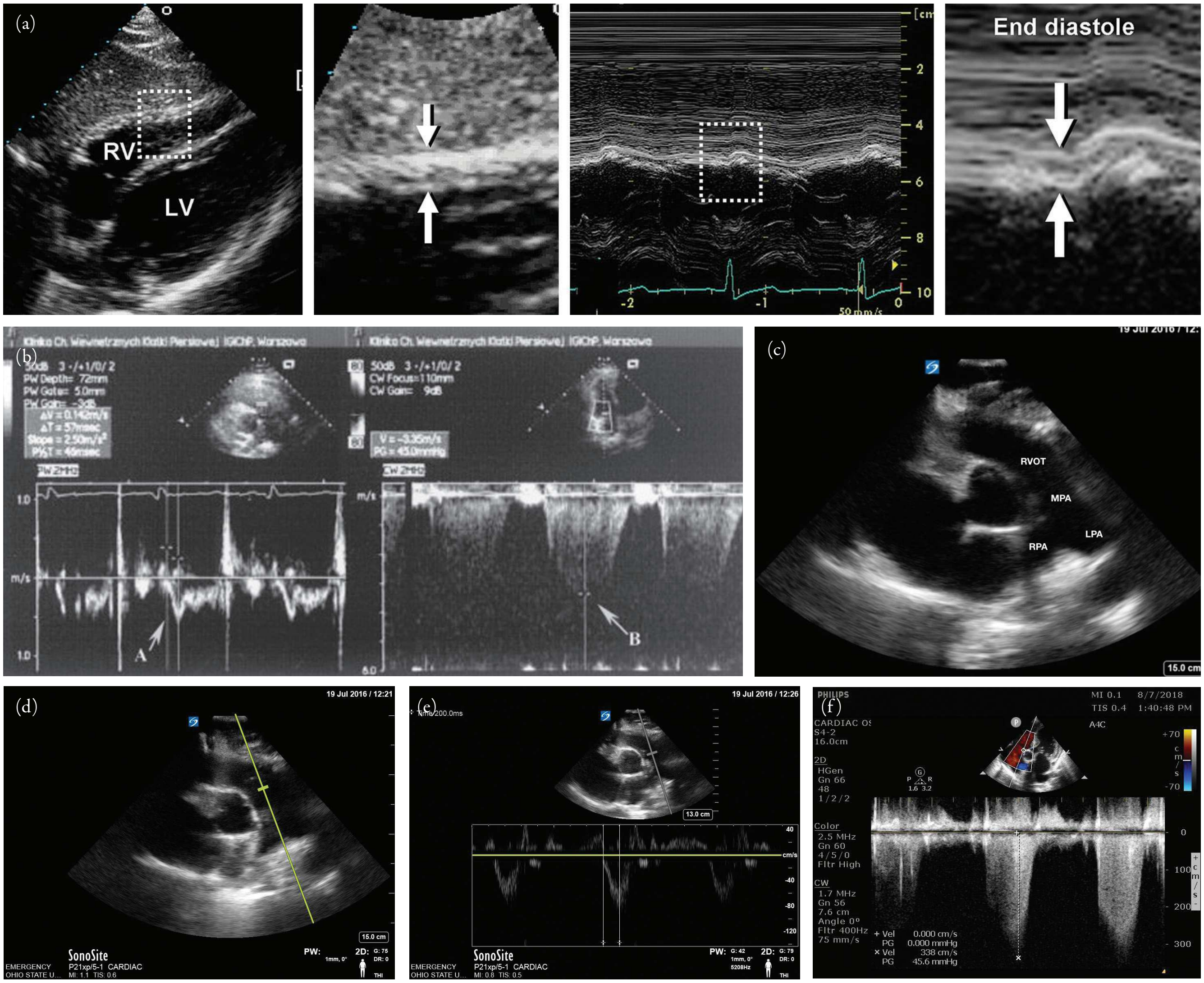

Figure 15.28 (a) **Measurement of end-diastolic right ventricular wall thickness.** (a) Subcostal 2-dimensional image of right ventricular wall. (b) Zoom of region outlined in (a) with right ventricular wall thickness indicated by *arrows*. (c) M-mode image corresponding to *arrows* in (b). (d) Zoom of region outlined in (c) with *arrows* indicating wall thickness at end-diastole. Adapted from Figure 5 of Rudski LG, Lai WW, Afilalo J, et al. Guidelines for the echocardiographic assessment of the right heart in adults: a report from the American Society of Echocardiography endorsed by the European Association of Echocardiography, a registered branch of the European Society of Cardiology, and the Canadian Society of Echocardiography. *J Am Soc Echocardiogr.* 2010;23(7):685–713; quiz: 786–788. doi:10.1016/j.echo.2010.05.010. (b) **A 60/60 sign in a patient with massive pulmonary embolism.** Left panel: assessment of pulmonary flow velocity profile with short (57 ms) acceleration time (arrow A). Right panel: measurement of maximal gradient of tricuspid insufficiency (45 mmHg; arrow B) revealed mildly elevated pulmonary artery pressure. Adapted from Figure 1 of Kurzyna M, Torbicki A, Pruszczyk P, et al. Disturbed right ventricular ejection pattern as a new Doppler echocardiographic sign of acute pulmonary embolism. Am J Cardiol. 2002;90(5):507–511. (c) **Parasternal short axis view at level of the pulmonic valve.** This view is required to acquire the pulmonary flow velocity for the 60/60 sign. RVOT = right ventricular outflow tract; MPA = main pulmonary artery; RPA = right pulmonary artery; LPA = left pulmonary artery. (d) **Pulsed-wave Doppler sampling gate placed at the right ventricular outflow tract to measure pulmonary flow velocity.** (e) **Measurement of pulmonary acceleration time.** (f) **Tricuspid gradient measurement.**

was originally suggested that this sign was highly specific for PE (McConnell et al. 1996). This was based on the theory that although chronic pulmonary hypertension may cause global RV dysfunction, only an acute increase in RV pressure would manifest with apical sparing. This high specificity was confirmed in several studies, with a meta-analysis showing over specificity of 97% (Fields et al. 2017). However, subsequently the specificity of this sign has been questioned. There have been several small studies that showed McConnell's sign occurs in patients with chronic pulmonary hypertension with similar frequency as in acute PE and that the positive predictive value was only 40% (Walsh and Moore 2015; Vaid et al. 2013), choice B. Additionally, a subsequent study compared the etiologies of those found to have a McConnell's sign and found that 32% did not have a PE, and many of that group had

Table 15.6 SENSITIVITY AND SPECIFICITIES OF ECHOCARDIOGRAPHIC FINDINGS TO DIAGNOSE ACUTE PE

FINDING	MEASURE THAT SUGGESTS ACUTE CAUSE	SENSITIVITY FOR PE	SPECIFICITY FOR PE	NOTES
RV hypertrophy	≤0.5 cm	Unknown	Unknown	RV wall thickening can also occur in cardiomyopathy and also can be a result of LV hypertrophy. A thickened pericardium can make measuring difficult. Accuracy of this finding for diagnosing chronic pulmonary hypertension unknown.
60/60 sign	If both the pulmonary acceleration time <60 msec AND tricuspid gradient <60 mmHg	24	84	Because these measurements are dependent on Doppler, there is risk of variability from change in angle of insonation.
McConnell's sign	The presence of a McConnell's sign	22	97	McConnell's sign can also occur in RV infarction. Depending on the population studied, this can significantly decrease the specificity.

Note. PE = pulmonary embolism; RV = right ventricular; LV = left ventricular.

Adapted from Table 15.2 of Fields JM, Davis J, Girson L, et al. transthoracic echocardiography for diagnosing pulmonary embolism: a systematic review and meta-analysis. *J Am Soc Echocardiogr*. 2017;30(7):714–723.e714. doi:10.1016/j.echo.2017.03.004.

pulmonary hypertension (Mediratta et al. 2016). Another reason that this sign is not specific for PE is that it can occur in RV infarction. Casazza et al. (2005) found that this sign seemed to be similarly prevalent in both of these diseases. In their population of patients with both PE and RV infarction, the specificity for PE dropped to 33%. Given the inconsistent available evidence, it can be difficult to know how to view this sign. The specificity for acute PE may increase after RV infarction has been ruled out. However, in this case, the EKG and cardiac markers were not yet available. What is clear is that it does indicate right ventricular dysfunction but may not be able to differentiate between acute and chronic causes of increased right-sided pressures. No studies have suggested that this sign would be specific for chronic pulmonary hypertension (choice D). All of the research does agree that this sign is far from sensitive for acute PE. McConnell's sign has not been reported in pericarditis, where echocardiographic findings (if any) would include pericardial effusion and pericardial thickening (choice C).

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Keywords/Tags: PE, Accuracy, diagnosis, RV strain, McConnell's, pulmonary hypertension

27. EXPLANATION

D. TR will still be useful in this patient. This vignette describes a patient with a history of chronic pulmonary hypertension in whom you are concerned for additional right heart strain from a PE. Patients with long-standing pulmonary hypertension likely will have evidence of increased right-sided pressures on their echocardiogram, making it difficult to diagnose strain from a new PE. Findings such as RV hypokinesis, RV dilation, septal bowing, and a decreased TAPSE can be found in both chronic and acute causes (choices B and C). However, there a few echocardiographic findings that can be helpful in determining the chronicity of the pressure overload on the right side of the heart. The main principle is that it takes a chronic process to build up the highest pressure. For example, a calculated systolic pulmonary artery pressure >60 mmHg is suggestive of a chronic process, as the heart is unlikely to be able to generate such pressures acutely (Condliffe et al. 2014). Although TR occur in both acute and chronic causes, a TR jet velocity >3.7 m/s is suggestive of a chronic process (Matthews and

McLaughlin 2008). The 60/60 rule similarly takes advantage of this principle by stating that if the pulmonary acceleration time is ≤60 ms and the tricuspid gradient is not >60 mmHg, it points toward an acute process (Figure 15.28b; Kurzyna et al. 2002). This was found to be 94% specific in 1 initial study but nonspecific in another study (Kurzyna et al. 2002; Lodato et al. 2008). For these reasons, TR measurements can hint at the chronicity of the pulmonary hypertension if the TR gradient is >60 mmHg (choice D). A McConnell's sign (hypokinetic RV free wall with preserved apical contractility) was also considered to be fairly specific for an acute cause of right heart strain, although there is conflicting data which may suggest it is not as accurate as previously thought. The finding of right ventricular hypertrophy points toward a more chronic process. While some of these findings may be specific, none of them are sensitive and, therefore, these signs should not be used to rule out the presence of PE (choice A).

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Keywords/Tags: Right heart strain, 60/60, McConnells, pulmonary hypertension, diagnosis, measurement

28. EXPLANATION

D. Repeat the images. The key finding in this apical 4-chamber view shown is that the transducer is erroneously flipped 180 degrees, creating a flipped image. This can have the unfortunate repercussion of misinterpretation of the study. One potential misinterpretation is that the LV will appear in the place of the RV, which could simulate an enlarged RV. It is not uncommon that novice sonographers flip their transducer during image acquisition, in part due to varying conventions for obtaining cardiac images (Moore 2008). For this reason, in the apical 4-chamber view it is important to be able to distinguish the right and left heart using other anatomical information, especially if you are not the person obtaining the images or are reviewing the images after the patient encounter. The shape of the RVs and LVs are distinct, with the RV normally having a more acute angle as it approached the apex compared to a more broadly rounded LV. In addition, the LV is generally larger and has a thicker myocardial layer. However, both of the aforementioned findings may not be true in the case of right heart pathology, such as can be seen in pulmonary hypertension. Fortunately, there are several other findings that can assist in making this determination. The left ventricular outflow tract, which can be seen from an apical 5-chamber view, identifies the LV from which it exits. The descending thoracic aorta is consistently deep to the left atrium on transthoracic imaging. The moderator band is a thickened trabecular that can be seen in the RV (Figure 15.29, Video 15.21). The tricuspid valve is slightly more apically located compared to the mitral valve. Knowledge of these clues used in distinguishing the left and right sides of an apical 4-chamber view can avoid accidental misdiagnosis. Ordering CT angiography (choice A), activating the cath labs (choice B), or starting anticoagulation (choice C) would not be appropriate next steps in management based only on the evidence of a single normal, albeit reversed, cardiac view.

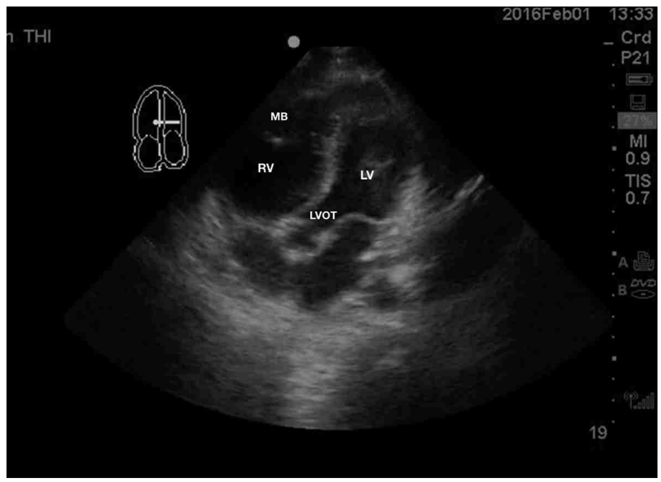

Figure 15.29 **Apical 5-chamber view in correct orientation.** Only the left ventricle will contain the left ventricular outflow tract (LVOT) and only the right ventricle will contain moderator bands (MB). LV = left ventricle; RV = right ventricle.

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Keywords/Tags: Right heart strain, acquisition, orientation, cardiac, anatomy

29. EXPLANATION

D. Direct visualization of incompetent valves on B-mode. Examination for venous insufficiency includes an assessment

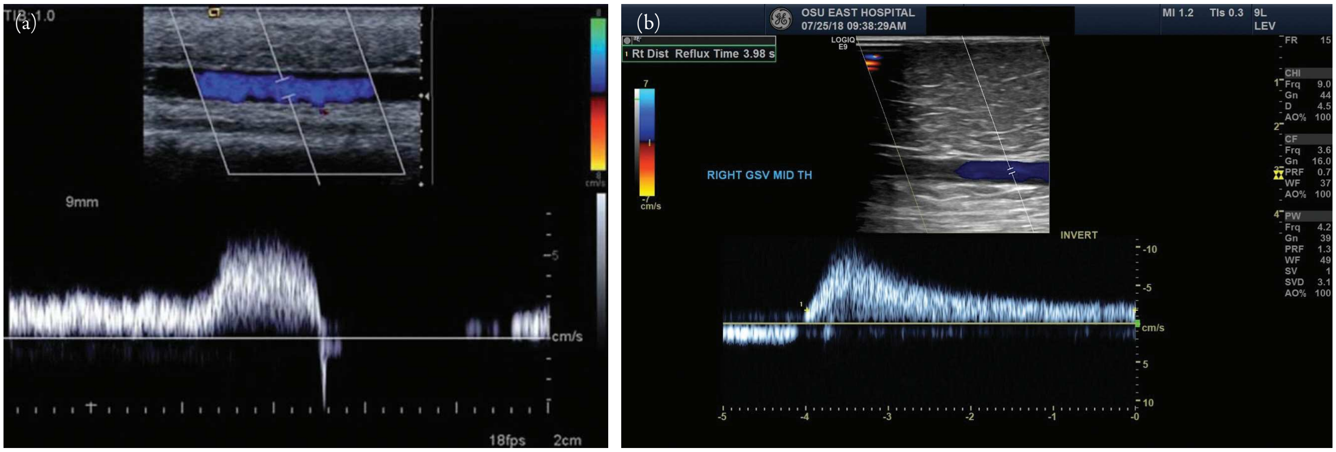

Figure 15.30 (a) **Competent superficial vein.** Well-optimized duplex image of flow in a competent superficial vein. Wide color box was used for a long segment of the vein to be visualized. Spectral waveform is large and clear. Spontaneous venous flow is seen in the left side of the spectral trace, followed by manual augmentation. There is a sharp "click" or "snap" of venous valve closure followed by a period of absent flow. Once arterial inflow refills the peripheral vascular bed, normal antegrade flow resumes again on the right side of the spectral Doppler trace. Adapted from Figure 1 of Necas M. Duplex ultrasound in the assessment of lower extremity venous insufficiency. *Australas J Ultrasound Med*. 2010;13(4):37–45. doi:10.1002/j.2205-0140.2010.tb00178.x. (b) **Incompetent superficial vein.** The reversal of flow last longer than 0.5 seconds after initiation of Valsalva.

of the superficial and deep veins, assessing for evidence of valvular incompetence. To maximize the detection of venous reflux, one must ensure the lower extremity veins are as engorged as possible. Patients, exam rooms, and gel should be warmed, and patients should be instructed to forego their compression stockings the day of testing. Factors that maximize the occurrence of reflux are scheduling exams later in the day and having the patient upright or in reverse Trendelenburg position. These factors will often also aid in identifying the popliteal vein during deep venous examination for the presence of thrombosis. In addition, generous use of the Valsalva maneuver for the proximal lower extremity and augmentation when interrogating the distal lower extremity can assist in visualizing reflux when present. Doppler with the target vein in long axis is used to visualize the blood flow within a vein, with attention to the direction of the blood flow during interventions (Figure 15.30a). Venous incompetence (or reflux) is identified when reversal of flow lasts longer than 0.5 seconds after Valsalva or augmentation (Figure 15.30b).

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Necas M. Duplex ultrasound in the assessment of lower extremity venous insufficiency. *Australas J Ultrasound Med*. 2010;13(4):37–45.

Keywords/Tags: Venous reflux, acquisition tips

30. EXPLANATION

D. PE. The lung ultrasound shows a subpleural consolidation, also known as a subpleural nodule. This is a finding that can be associated with a number of pathologies. These findings can be present in PE, malignancy, or viral infections. In PE, these are thought to be caused by atelectasis, peripheral infarction, or hematoma. They are described as triangular or rounded anechoic segments extending from the pleural line. In PE there are usually multiple lesions 0.5 to 3 cm in size. Smaller subpleural consolidations are nonspecific. In 1 study, these lung findings alone were 94.9% specific, while only 71.0% sensitive (Mathis et al. 2005). In this case, 66% of the lesions were found in the posterior basal lung segments. A meta-analysis of 7 studies found a mean sensitivity of 87% and a mean specificity of 81.1% (Squizzato et al. 2013). In a group of patients with higher pretest probability for PE, subpleural consolidations were 97.6% specific (Nazerian et al. 2014). Choice A is incorrect because there is good lung sliding of the pleura shown here, ruling out pneumothorax in this area of the lung. A malignant lesion in the lung (choice C) can show similar characteristics although these lesions can be larger. Pneumonia (choice B) can cause lung consolidations as well, but in this clinical situation a PE is more likely.

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Keywords/Tags: Venous reflux, acquisition tips

16.

TESTICULAR ULTRASOUND

Delia L. Gold, Michael I. Prats, Fara F. Bellows, and Creagh T. Boulger

QUESTIONS

1. A 21-year-old male presents with left-sided testicular pain that began suddenly 4 hours ago. His vital signs are within normal limits. On exam, he is noted to have a significantly enlarged left hemiscrotum that is tender to palpation. You would like to perform a bedside ultrasound to further evaluate his pain. Which of the following probes would *not* be appropriate for your exam?

A. Linear 14-6 MHz
B. Linear 10-5 MHz
C. Phased array 5-1 MHz
D. Linear 13-6 Hz

2. A 23-year-old male presents to the emergency department (ED). He states that he fell off of his mountain bike and afterwards began having testicular pain. His vital signs are temperature 98.5°F, blood pressure 110/76, heart rate 101, respiratory rate 14, and pulse oximetry 98%. On exam, you notice an abnormal lie to his right testicle and the absence of a cremasteric reflex. You are concerned that he may have testicular torsion. You perform an ultrasound of the scrotum (Figure 16.1). What is the next step in adjusting your ultrasound?

Figure 16.1

A. Adjusting the focal zone
B. Changing the dynamic range
C. Evaluation with power Doppler mode
D. Utilizing the zoom feature to better delineate testicular tissue

3. You are in the ED examining a 13-year-old male presenting with acute left testicular pain. He presents with his mother and both appear very anxious. The pain has been present for 4 hours and is severe. His vital signs are temperature of 99.0°F, blood pressure of 112/75, heart rate of 115, pulse oximetry of 98%, and respiratory rate of 18. On exam, the left testicle is erythematous, swollen, and has tenderness to palpation. You are able to perform a quick ultrasound of the left testicle, which shows some blood flow, but the patient is very embarrassed and is refusing to let you ultrasound the right asymptomatic testicle. What is the best argument you can make to this patient and mother regarding the need for an ultrasound examination of the nontender testicle?

A. The patient and mother are correct; you don't need to examine the contralateral testicle with ultrasound as physical exam should be sufficient to rule out torsion.
B. It is very common to have simultaneous bilateral testicular torsion, therefore you need to evaluate both testicles with ultrasound.
C. State that as the physician you want to examine both testicles, therefore he has no choice.
D. Explain that an ultrasound evaluation for testicular torsion includes comparing the sonographic appearance of the abnormal testicle with the normal testicle.

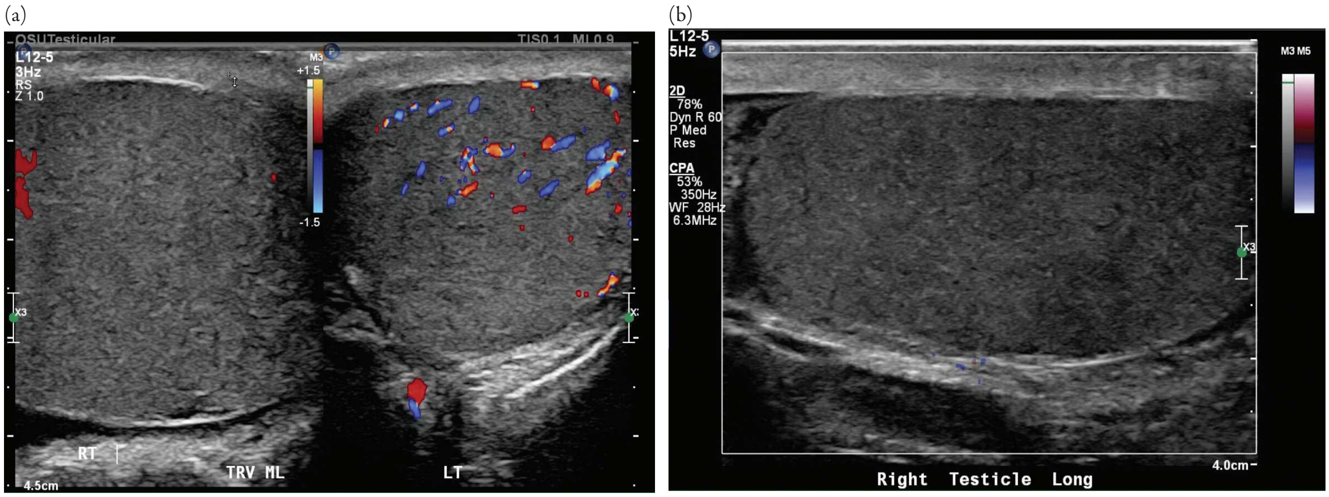

Figure 16.2 (a) **"Buddy shot" (both testicles seen on ultrasound)**. Right testicle shows decreased color Doppler flow compared to the left testicle. (b) **Right testicle with absent color Doppler flow**.

4. You are evaluating a 35-year-old male with right testicular pain that began 4 hours ago while mowing the lawn. You note his vital signs are temperature 98.4°, blood pressure 145/82, heart rate 101, pulse oximetry 95%, and respiratory rate 12. He appears uncomfortable. Your testicular exam reveals an elevated right testicle with the absence of a cremasteric reflex. You work in a rural urgent care with the closest urologist 5 hours away. Bedside ultrasound reveals the clip shown in Figure 16.2a and Figure 16.2b. You attempt to manually detorse the testicle, but you are unsuccessful. You have spoken to the urologist who has accepted this patient and plans to operate; however, the patient is refusing transport by air and would rather drive himself. Which of the following is *not* a correct statement?

A. If torsion is surgically repaired within 6 hours of presentation, there is an 80% to 100% chance of complete salvageability.
B. Salvage rate drops to about 20% after 12 hours since onset.
C. Of those taken to surgery, 20% may not have testicular torsion.
D. Complete infarction of the testicle is likely after 24 hours of onset of symptoms.

5. A 31-year-old man with no known medical history presents to the ED with lower abdominal pain radiating to bilateral testicles. His vital signs show temperature 98.0°F, blood pressure 154/92, heart rate 85, pulse oximetry 98%, respiratory rate 12. His exam reveals normal-appearing scrotum. There is no erythema and no testicular or epididymal tenderness. Your bedside ultrasound shows the image in Figure 16.3. How would you counsel the patient?

A. These ultrasound findings are concerning for malignancy. Close follow-up is recommended.
B. These ultrasound findings are most likely benign. No specific further work up is necessary at this time.
C. These ultrasound findings are equivocal. Further diagnostic testing is required.
D. These ultrasound findings are concerning for infection. Oral antibiotics are indicated.

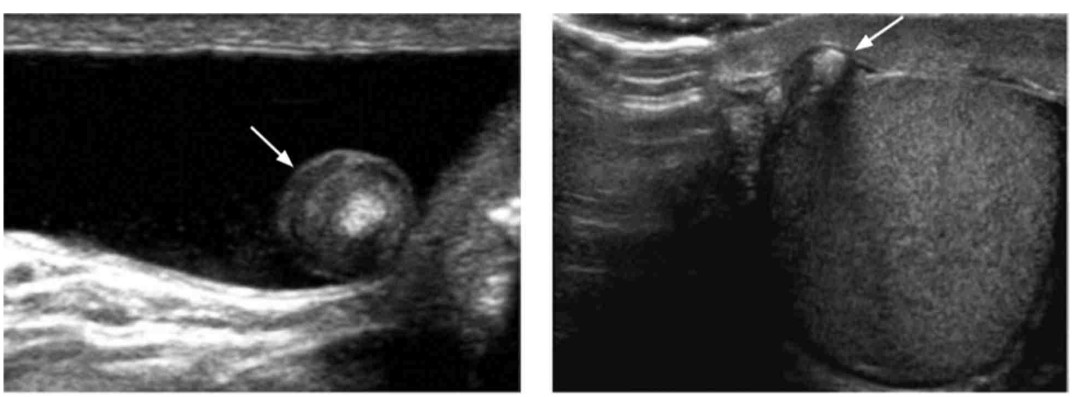

Figure 16.3

6. A 25-year-old male presents with left testicle pain. He reports that this pain began suddenly 2 hours ago, waking him from sleep. The pain went away after several minutes and he was able to sleep through the night. The pain began again this morning so he came to the ED. On your exam, he reports that he is no longer having pain. His vital signs show a temperature of 98.9°F, blood pressure of 110/72, heart rate of 78, pulse oximetry of 98%, and respiratory rate of 14. His scrotum appears normal and symmetric. There are no palpable masses and no tenderness to the testicles. You decide to perform a testicular ultrasound and obtain the image in Figure 16.4. What is the appropriate interpretation and medical decision-making?

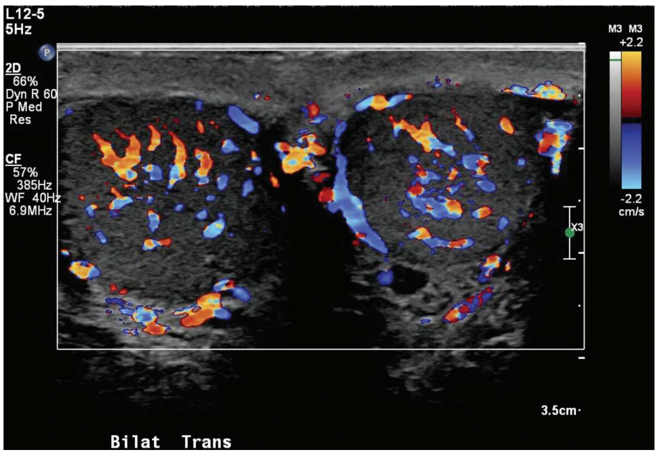

Figure 16.4

A. The ultrasound is normal. Discharge home with return precautions.
B. The ultrasound is concerning for asymmetric blood flow. This patient likely has testicular torsion and should go to the operating room.
C. The ultrasound shows increased blood flow to bilateral testicles. This is concerning for bilateral orchitis. Treat with antibiotics and urology follow-up.
D. The ultrasound is normal. Based on clinical history, intermittent testicular torsion is possible. Consult urology.

7. A 12-year-old male presents to your ED with right-sided testicular pain for the past 2 days. His vital signs are temperature 98.5°F, blood pressure 109/68, heart rate 68, pulse oximetry 97%, and respiratory rate 12. On exam, he appears uncomfortable. He is exquisitely tender to the superior aspect of the scrotum in the area between the testicle and head of the epididymis. You note a small area of bluish discoloration to the skin over the upper pole of the testicle. What findings would you most likely expect to see on ultrasound?

A. Decreased Doppler signal in the right testicle
B. Deceased Doppler signal in the right epididymis
C. A spherical appendage superior to the right testicle with no blood flow
D. A spherical appendage superior to the right testicle with increased blood flow compared to the left

8. A 22-year-old male presents to your ED with left-sided scrotal pain. He states the symptoms began 3 to 4 days earlier. There was no known trauma. He denies any medical history. On exam, his vital signs are temperature of 99.0°F, blood pressure of 128/78, heart rate of 84, pulse oximetry of 96%, and respiratory rate of 14. Your exam reveals a left testicle that is erythematous and tender to palpation. The left side appears swollen compared to the right. There are no palpable masses. Bilateral cremasteric reflexes are intact. The penis appears normal. The triage nurse had ordered testing prior to your evaluation and you note that the patient has a normal complete blood count and a urine dip with small leukocyte esterase and no nitrites. You decide to perform a bedside ultrasound to further investigate the left epididymis (see Figure 16.5a) and testicle (see

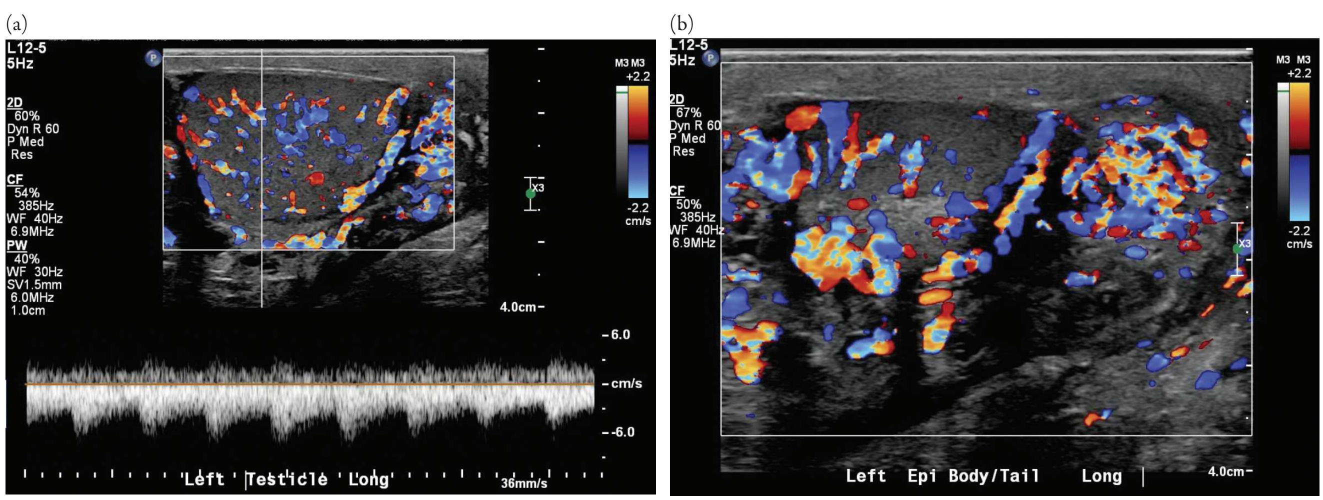

Figure 16.5

Figure 16.5b). Based on the imaging, what is the most likely diagnosis?

A. Epididymo-orchitis
B. Torsion of the appendix testis
C. Testicular torsion
D. Testicular cyst

9. A patient presents with acute onset unilateral testicle pain. The vital signs are unremarkable. Physical exam reveals erythema, tenderness, and an abnormal lie to the testicle. An ultrasound is performed and shows decreased blood flow on the affected side. Which would represent the most common demographic of patient with this disease?

A. 2-year-old male
B. 12-year-old male
C. 20-year-old male
D. 50-year-old male

10. A 26-year-old male presents after a fall in a local park. He complains of groin and abdominal pain. He states he was performing skateboarding tricks and fell straddling a rail. His vital signs show temperature 97.9°F, blood pressure 128/82, heart rate 113, pulse oximetry 97%, and respiratory rate 14. His abdominal exam is benign. On his genitourinary exam you notice diffuse scrotal ecchymosis and swelling. Both testicles are tender to palpation. Which of the following tests is preferred for the initial workup?

A. Ultrasound
B. Magnetic resonance imaging (MRI)
C. Computed tomography (CT)
D. Urinalysis

11. A 67-year-old patient presents to the ED complaining of scrotal swelling. He has a history of diabetes and high blood pressure. He has had the pain for 4 months, and he states he was treated with antibiotics for epididymitis. His vital signs are temperature of 98.0°F, blood pressure of 155/90, heart rate of 83, pulse oximetry of 96%, and respiratory rate of 14. On exam, his scrotum is asymmetric with swelling on the right side. You decide to perform an ultrasound and obtain the image in Figure 16.6. The patient is very concerned about testicular cancer as he had a friend recently diagnosed. How would you counsel the patient given the findings?

A. Given the increased flow on the affected testicle, this is likely an infectious process.
B. This is a normal variant.
C. There are no masses, making malignancy unlikely.
D. Further testing is needed to rule out malignancy.

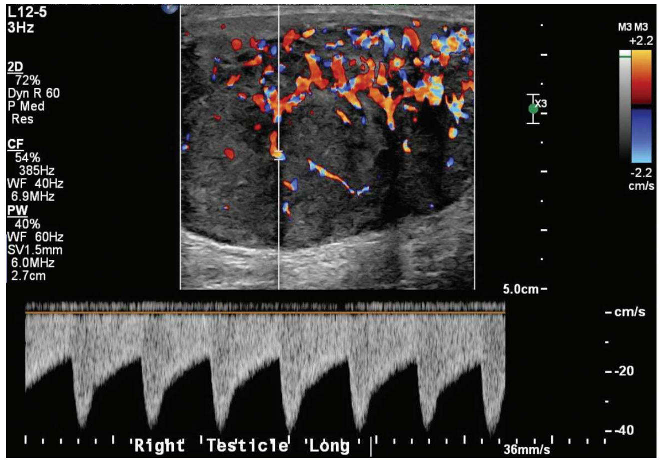

Figure 16.6

12. A 12-year-old male presents with testicular pain after being kicked in the groin during a soccer game. His vital signs show temperature 98.5°F, blood pressure 115/76, heart rate 107, pulse oximetry 98%, respiratory rate 16. He appears uncomfortable. His exam reveals a swollen scrotum with erythema and some bruising. You quickly perform a testicular ultrasound, shown in Figure 16.7. Which of the findings is *not* seen in the image?

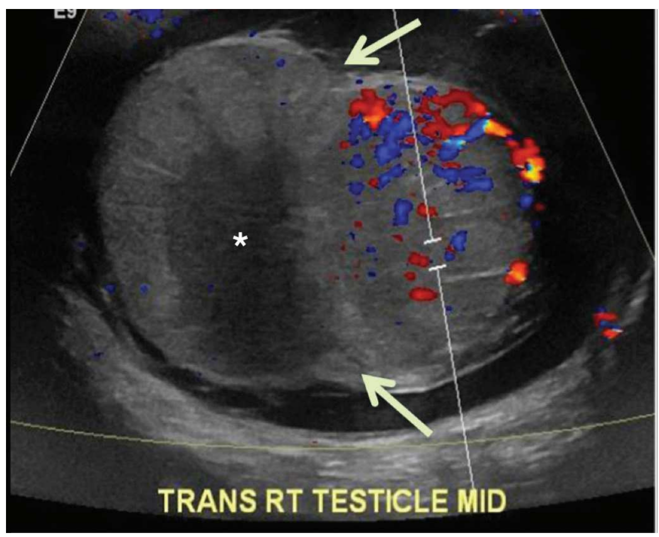

Figure 16.7

A. Complete testicular ischemia
B. Fracture line
C. Hematocele
D. Irregular contour

13. A 16-year-old male is hit in the groin with a hockey puck while playing a pick-up game of hockey with his friends. The injury occurred 1 hour ago and he complains

of worsening swelling and pain in his left testicle. His vital signs show a temperature of 97.9°F, blood pressure of 121/77, heart rate of 90, pulse oximetry of 95%, and respiratory rate of 14. On exam, you notice that there is asymmetric swelling of the left hemiscrotum. There is developing ecchymosis to the anterior scrotum. The testicle is exquisitely tender. You perform a bedside ultrasound, shown in Figure 16.8. Which of the following statements is *false* regarding the finding (arrows) on this image?

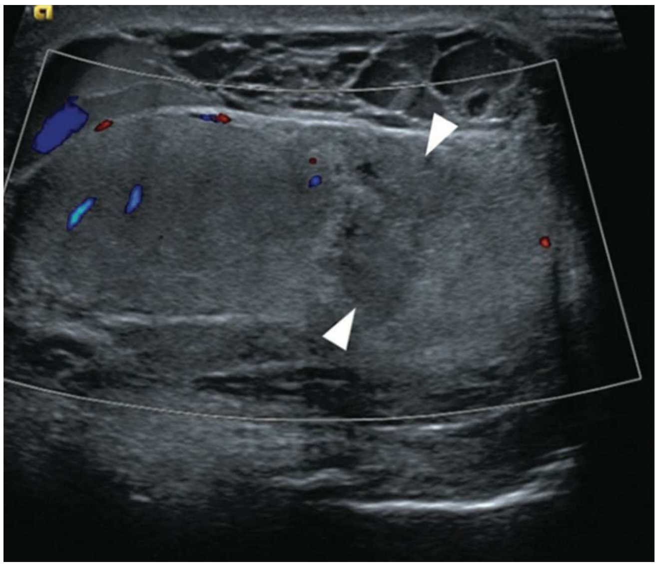

Figure 16.8

A. Color Doppler would show no flow within the hypoechoic line.
B. This indicates testicular fracture.
C. There is no evidence of testicular rupture.
D. This is a sensitive finding.

14. A 67-year-old male presents to the ED with groin pain. He has a history of hypertension, diabetes, and high cholesterol. He lives in a rehabilitation facility, and his aids state he has been complaining of worsening groin and genital pain for the past 2 days. His vital signs are temperature 101.2°F, blood pressure 118/78, heart rate 119, pulse oximetry 94%, and respiratory rate 16. On examination of his groin you notice diffuse erythema over his scrotum, extending onto his bilateral thighs and perineum. The area is very tender to palpation, and you think you feel crepitus. You suspect Fournier's gangrene. You perform an ultrasound. All of the following sonographic findings might be expected for this diagnosis *except*:

A. Hyperechoic "dirty" shadowing in scrotal wall
B. Heterogenous echogenicity of the left testicular and epididymis
C. "Cobblestoning" in the soft tissue
D. Thickened scrotal wall and anechoic fluid surrounding the testicle

15. You are taking care of a 14-year-old male in your ED who has left-sided scrotal pain and is concerned he could have gonorrhea because he learned about sexually transmitted infections in health class. He has no significant past medical history. His vital signs are normal. There is no tenderness to his testicles or epididymides. You perform an ultrasound and find the image in Figure 16.9. Based on your findings, what is his most likely diagnosis?

A. Epididymitis
B. Reactive hydrocele
C. Testicular tumor
D. Varicocele

16. A 36-year-old male police officer presents to the ED with testicular pain. He states that he was kneed in the groin while attempting to make an arrest. He notes severe pain in his left testicle. On exam, he is well appearing but appears in obvious pain. His vital signs show a temperature of 98.6°F, blood pressure of 116/65, heart rate of 68, pulse oximetry of 98%, and respiratory rate of 12. On exam, you notice significant swelling of the left hemiscrotum and diffuse purple ecchymosis. You perform an ultrasound and obtain the image in Figure 16.10. What is the most likely diagnosis?

A. Traumatic epididymitis
B. Testicular torsion
C. Testicular rupture
D. Hematocele

17. A nurse calls you to triage to see a patient with scrotal pain. The patient is a 22-year-old man who states he woke in the middle of the night with right-sided testicular pain. He has no known medical problems. He notes associated nausea and vomiting. He denies trauma. His vital signs are normal. You move the patient to a room for an examination. He has a normal-appearing scrotum but does have severe tenderness to the right testis. You are concerned that he could have testicular torsion. You page the on-call urologist and call for a sonographer to perform a comprehensive scrotal ultrasound. The sonographer calls back stating that they are performing another emergent study and will not be able to do the study for 20 minutes. You perform an ultrasound that shows decreased color and power Doppler in the right testicle compared to the left. Which of the following statements is true?

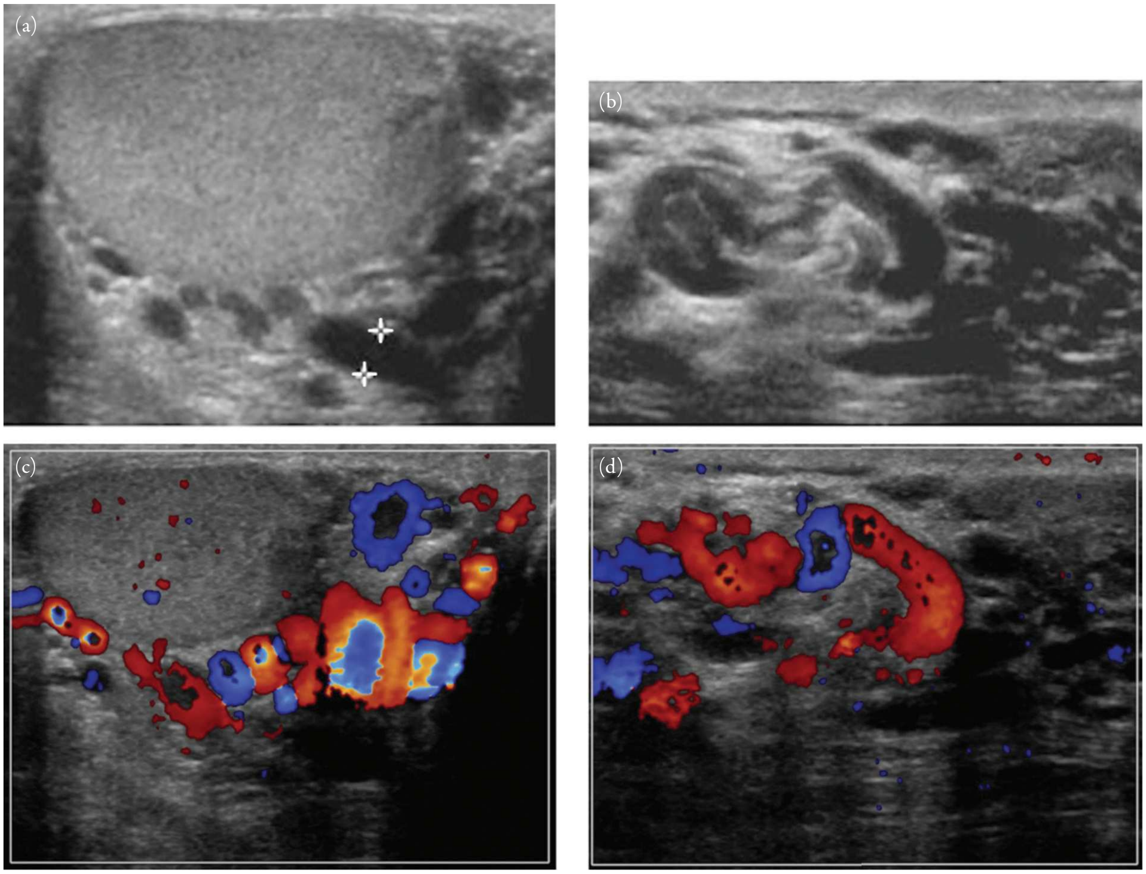

Figure 16.9

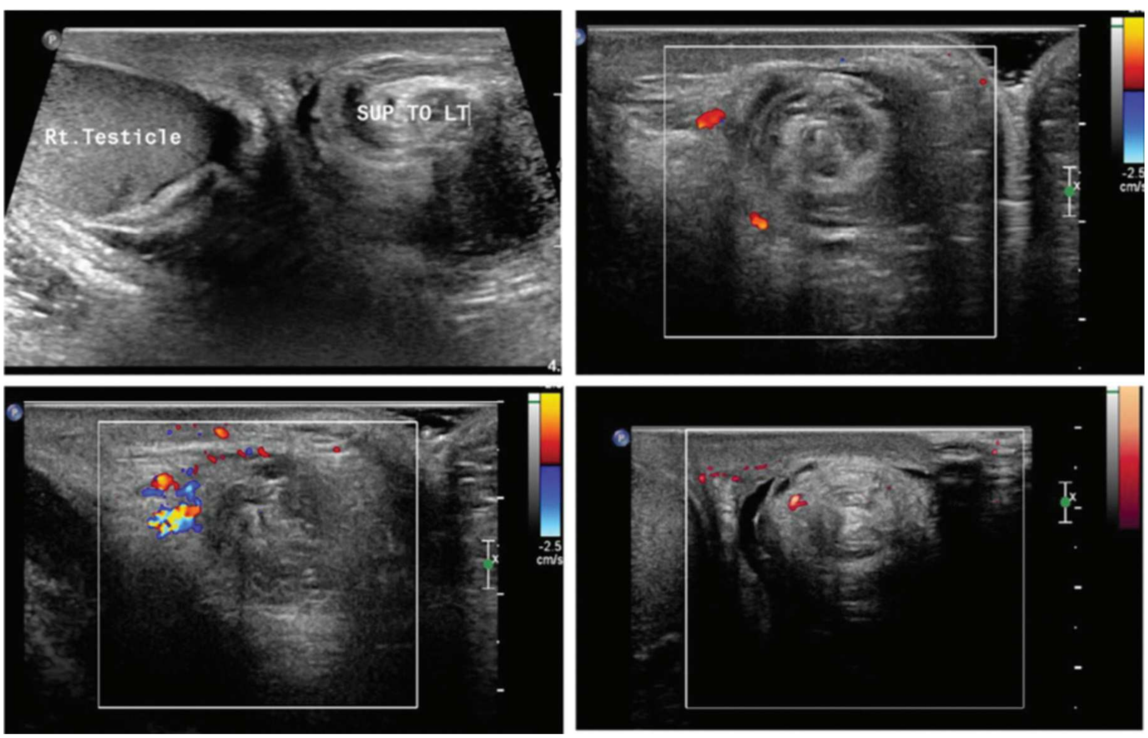

Figure 16.10

A. Clinician-performed ultrasound examinations for testicular torsion should not be performed because it can delay the diagnosis.
B. Physical examination is sufficiently accurate to rule out testicular torsion without further studies.
C. Point-of-care ultrasound machines lack the Doppler capabilities to accurately diagnose testicular torsion.
D. Clinician-performed ultrasound examinations for testicular torsion is accurate.

18. A 22-year-old man presents overnight to the ED with sudden-onset right testicular pain that woke him from sleep. He has no past medical history. His pain started approximately 2 hours ago. His vital signs are normal. Exam is significant for erythema of the right hemiscrotum and a small hydrocele. Ultrasound with color and pulsed wave Doppler shows flow to the right testicle, but it is diminished compared to the left testicle. The next step is:

A. Diagnose orchitis and discharge home with antibiotics.
B. Repeat ultrasound in 12 hours.
C. Consult urology for surgical management of testicular torsion.
D. Attempt manual detorsion and call urology in the morning.

19. A 67-year-old man presents to the family practice office with a left testicular mass. He is otherwise healthy without significant past medical history. On exam, the left testicle does have a palpable mass that is mildly tender. No skin changes or fistula are seen. An ultrasound is performed of the left testicle (see Figure 16.11a and Figure 16.11b). The right testicle is unremarkable. The differential diagnosis includes all of the following *except*:

A. Torsion of the appendix testis.
B. Granulomatous orchitis.
C. Testicular seminoma.
D. Testicular lymphoma.

20. A 46-year-old man presents to your office reporting right groin pain. He is quite active and regularly participates in triathlons and weightlifting competitions. His pain started after a particularly strenuous exercise. He denies nausea, vomiting, or change in bowel habits. His vital signs are temperature 98.4°F, blood pressure 110/64, heart rate 62, pulse oximetry 99%, and respiratory rate 12. His physical exam is concerning for possible right direct inguinal hernia. Which ultrasound technique may most strongly assist in diagnosis?

A. Using a low-resolution transducer
B. Having the patient hold his breathing and cough while you scan
C. Reducing the hernia with the ultrasound probe after Valsalva
D. Starting at the internal inguinal ring and then working inferior and medial toward the external ring

21. A 35-year-old man presents to your office with left scrotal swelling for the past 3 years. The swelling has slowly increased and now the left hemiscrotum is approximately the size of a large lemon. He is otherwise healthy and reports no past medical history. His vital signs are normal. On exam, you confirm the left hemiscrotum is enlarged. There is no tenderness to

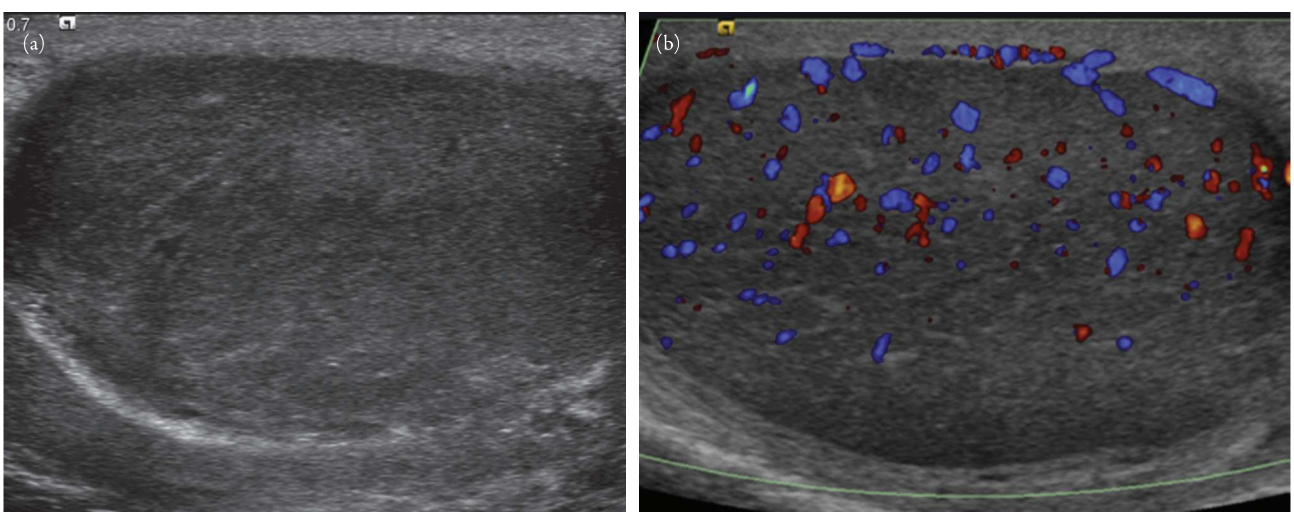

Figure 16.11

his left testicle. The right testicle and hemiscrotum are unremarkable. You perform an ultrasound (see Figure 16.12). What is the most likely diagnosis?

Figure 16.12

A. Hydrocele
B. Hematocele
C. Pyocele
D. Epididymal cyst

22. A 19-year-old man presents with testicular pain for 6 months. His pain is described as a 2/10 on a pain scale, dull, intermittent, without associated nausea or vomiting. His vital signs show temperature 98.0°F, blood pressure 124/82, heart rate 85, pulse oximetry 98%, and respiratory rate 12. His exam reveals normal appearing scrotum. There is no erythema and no palpable testicular masses, nor testicular or epididymal tenderness. Ultrasound shows the image in Figure 16.13. What is the most likely sonographic diagnosis?

A. Seminoma
B. Microlithiasis
C. Lymphoma
D. Normal testicle

23. A 9-year-old boy presents to the ED with bilateral scrotal pain and swelling. He was previously in normal state of health. He is up to date on his immunizations. His vital signs are normal for his age. Physical exam reveals bilateral scrotal swelling and mild tenderness. You also

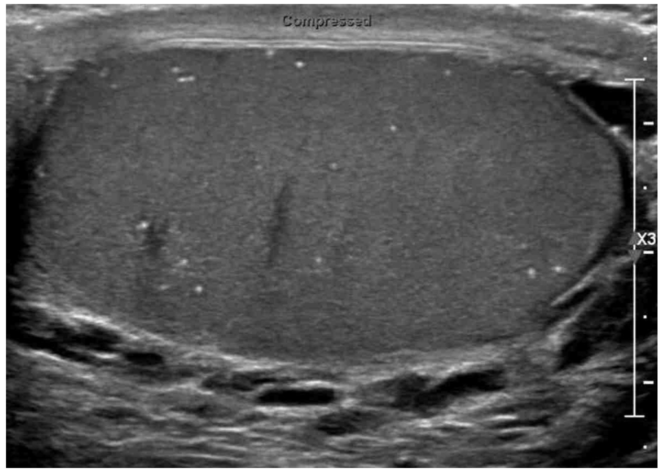

Figure 16.13

notice a rash on his bilateral lower extremities concerning for Henoch–Schonlein purpura. What testicular ultrasound finding would *not* be associated with this disease?

A. Epididymal enlargement
B. Scrotal wall thickening
C. Reactive hydrocele
D. Testicular tumor

24. A 26-year-old man presents to the ED complaining of penile pain. He was having intercourse and felt a buckle while attempting insertion. He heard a "pop" and experienced immediate detumescence. His vital signs are temperature 98.5°F, blood pressure 129/82, heart rate 95, pulse oximetry 96%, and respiratory rate 16. On exam, his phallus is ecchymotic and edematous (see Figure 16.14).

Figure 16.14

What penile ultrasound findings are expected to be seen?

A. Soft tissue edema and rupture of tunica albuginea
B. Absence of Doppler flow in the corpora cavernosa
C. Dilation of the urethra
D. Subcutaneous air

25. A 22-year-old male presents with right sided testicular pain for the past 2 days. He notes that he is sexually active with multiple partners. His vital signs are normal. There is mild erythema and swelling to his right hemiscrotum. There is mild tenderness to his testicle. You obtain an ultrasound and see the image in Figure 16.15. What is this finding and what does it indicate?

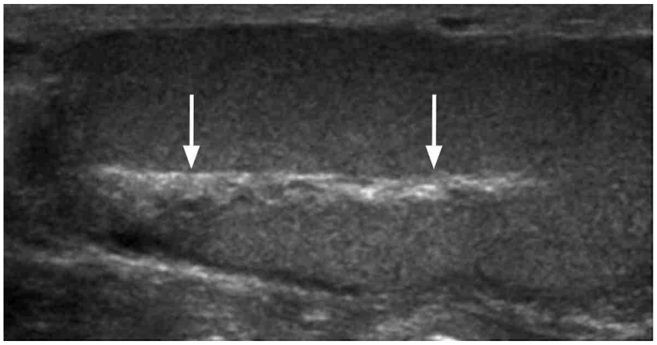

Figure 16.15 Adapted from Figure 2 of Kühn AL, Scortegagna E, Nowitzki KM, Kim YH. Ultrasonography of the scrotum in adults. *Ultrasonography.* 2016;35(3):180–197. doi:10.14366/usg.15075.

A. Fracture line; indicates testicular fracture
B. Mediastinum testis; indicates normal finding
C. Heterogeneous testicular tissue; indicates orchitis
D. Linear tumor; indicates likely malignancy

26. A 42-year-old man presents with a left-sided testicular mass that he has noticed over the past 6 months. At first, he was not concerned, but he now believes it is increasing in size. He has a past medical history of hypertension. He denies any fever, weight loss, or other symptoms. His vital signs are unremarkable. On exam, his scrotum appears normal but his left testicle appears larger than the right. There is no tenderness to palpation. You perform an ultrasound and find the image in Figure 16.16. Which of the following is the most appropriate next step?

A. Consult urology for possible operative drainage.
B. Order oral antibiotics and close follow-up.
C. Refer for close outpatient follow-up.
D. Reassure that this is a benign finding.

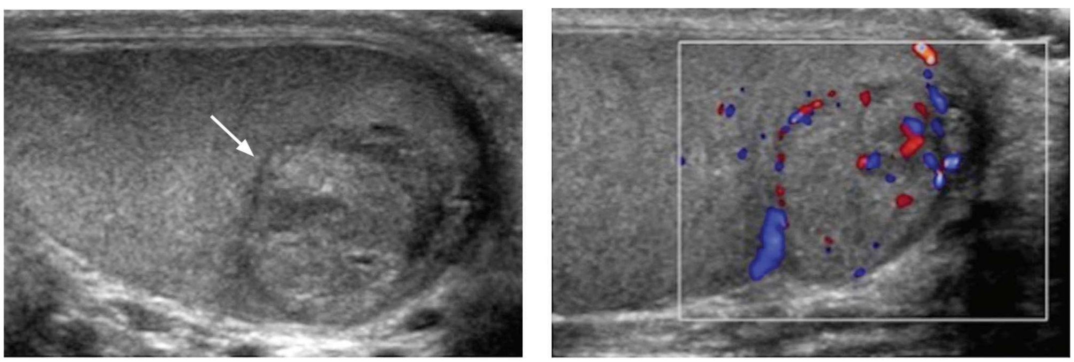

Figure 16.16 Adapted from Figure 20 of Kühn AL, Scortegagna E, Nowitzki KM, Kim YH. Ultrasonography of the scrotum in adults. *Ultrasonography.* 2016;35(3):180–197. doi:10.14366/usg.15075.

ANSWERS

1. EXPLANATION

C. Phased array 5-1MHz. To correctly image the testicle, one needs to choose a high-frequency probe that can provide the necessary resolution for detailed evaluation of the scrotum and its contents (Dogra and Bhatt 2004; AIUM et al. 2011). A hockey stick (Figure 16.17) or rectangular linear probe would be ideal to scan the testicle (choices A, B, D). There is no indication for a phased array probe in the scrotal exam (choice C), because although it does feature a lower frequency, the pie-shaped image of the probe provides less view of superficial structures. The curvilinear probe may be more appropriate in the event the linear probe can provide insufficient depth.

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Keywords/Tags: Testicle, image acquisition

Figure 16.17 **Different types of linear transducers.** All of these transducers would be adequate for testicular ultrasound.

2. EXPLANATION

C. Evaluation with power Doppler mode. Blood flow to the testicles is provided by the right and left testicular arteries, which arise from the abdominal aorta. The testis has collateral blood supply from the cremasteric artery (branch of external iliac artery) and the ductus deferens artery (branch of internal iliac artery); see Figure 16.18a. The venous blood from the testicles drains into the testicular veins which drain directly into the IVC. In the case of testicular torsion, the blood supply to the testicles, as well as the venous drainage, can be compromised. In healthy testicles, low-velocity blood flow predominates, so it is of utmost importance that power Doppler is utilized to sufficiently evaluate for evidence of torsion (choice C). Power Doppler is distinguished from color Doppler in that it does not determine the relative direction of the blood flow. However, it has a greater sensitivity for lower flow states such as may be found in the testicle (Figure 16.18b). Given this concerning clinical scenario, even with symmetric power Doppler flow to the bilateral testis, further urologic evaluation may be necessary if patient is continuously symptomatic.

Adjusting the focal zone (choice A) changes the point at which the ultrasound beam converges, which can create a high resolution at specified depth. Changing the dynamic range (choice B) changes the number of grays available to create the image. Utilizing the zoom feature (choice D) creates a larger rendering of an area on the screen. Although these changes in knobology may help improve the B-mode image, they are not appropriate adjustments when concerned about the amount of vascular flow.

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Lin EP, Bhatt S, Rubens DJ, Dogra VS. Testicular torsion: twists and turns. *Semin Ultrasound CT MR*. 2007;28(4):317–328.

Keywords/Tags: Testicle, anatomy, vascular supply, power Doppler imaging, torsion

3. EXPLANATION

D. Explain that an ultrasound evaluation for testicular torsion includes comparing the sonographic appearance of the abnormal testicle with the normal testicle. There are several reasons why it is important for a sonographic evaluation of the testicles to include bilateral testis (choice D). Most obviously, symmetry is key in differentiating pathology from anatomic variants (Blaivas and Mundy 2002; Kühn et al. 2016). This is true both for the B-mode grayscale appearance of the testicular tissues, as well as the Doppler flow seen. Furthermore, the Doppler parameters need to be optimized with low wall filter, low pulse repetition frequency, and minimal artifact while maintaining sensitive settings (see Table 16.1; Lin et al. 2007). The asymptomatic contralateral testicle should be used to set these parameters as a baseline. Additionally, patients can be uncomfortable with this exam due to the sensitive location and pain, so ultrasound examination of

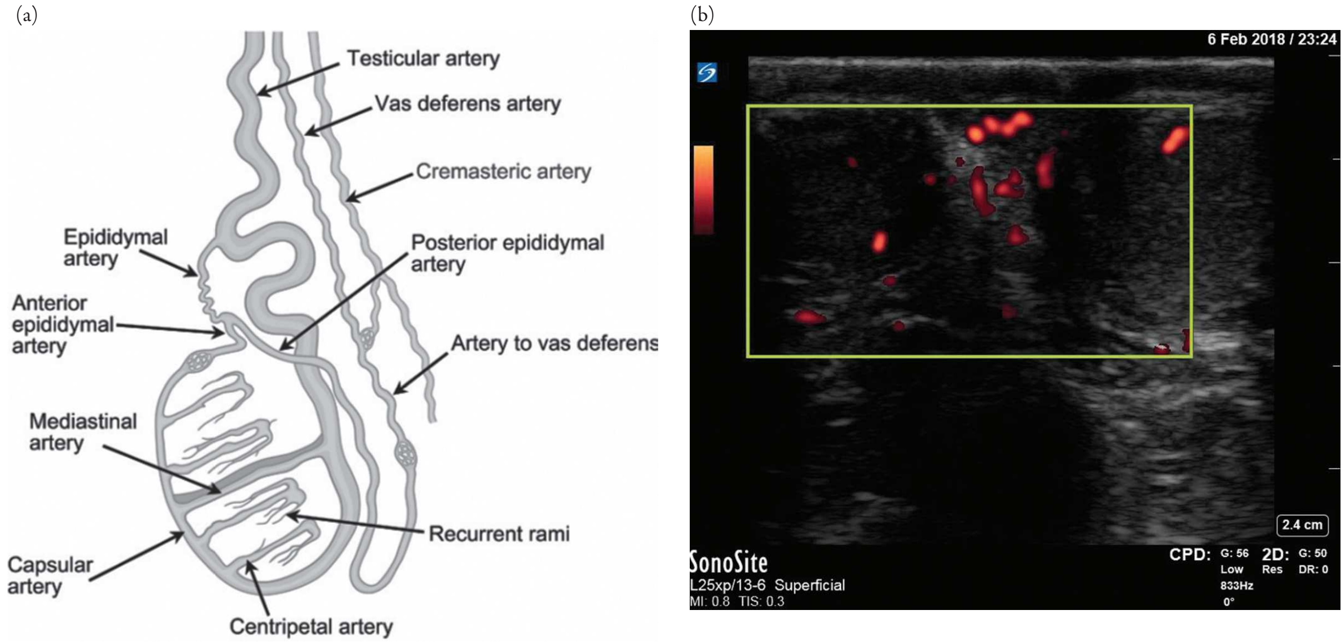

Figure 16.18 (a) **Testicular blood supply.** Adapted from Figure 2A of Lin EP, Bhatt S, Rubens DJ, Dogra VS. Testicular torsion: twists and turns. *Semin Ultrasound CT MR*. 2007;28(4):317–328. doi:10.1053/j.sult.2007.05.008. (b) **Power Doppler evaluation of normal testicles showing the low flow state of the testicles.**

Table 16.1 OPTIMIZING COLOR FLOW DOPPLER IMAGE

Color box	Keep the color box small to improve frame rate and obtain better color resolution
Doppler gain	Set this just below the noise level
Color scale PRF	Low PRF is more sensitive to low flow vessels but may lead to aliasing
Beam steering	Adjust to obtain satisfactory vessel angle (i.e., not 90°)
Gate size (sample volume)	Set the sample volume to a correct size, usually two-thirds of the vessel lumen
Wall filter	A high filter cuts out the noise but also the slower flow states. Keep the filter at 40–100 Hz
Focal zone	The color flow image is optimized at the focal zone, so place it where the vessels are expected

Note. PRF = pulse repetition frequency.

the unaffected hemiscrotum can familiarize the patient with the process. Therefore, it is inadequate to examine only the symptomatic testicle (choice A). Although bilateral simultaneous testicular torsion can occur, it is known to be very rare and generally in neonates (choice B; Beliaev and Mundy 2013). The utmost care should be taken to keep the patient and family comfortable during this sensitive ultrasound exam (choice C). Figure 16.19 shows both testicles being scanned with a linear transducer with a

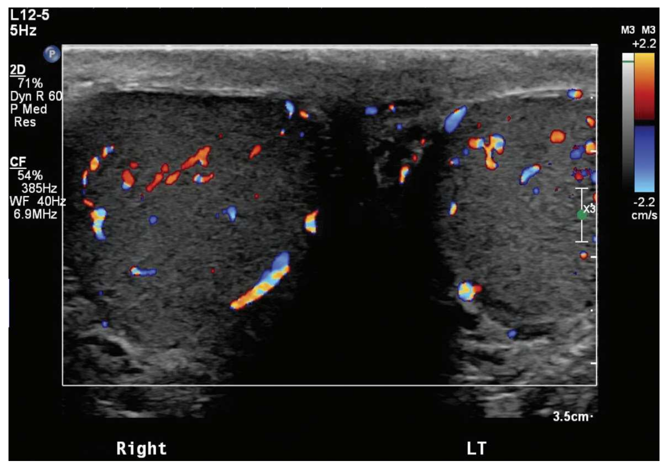

Figure 16.19 **Color Doppler of bilateral testes.**

wall filter setting of 40 Hertz. The pulse repetition frequency has been set such that the Doppler scale ranges from 2.2 cm/s to –2.2 cm/s.

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Lin EP, Bhatt S, Rubens DJ, Dogra VS. Testicular torsion: twists and turns. *Semin Ultrasound CT MR*. 2007;28(4):317–328.

Keywords/Tags: Doppler, proper exam technique, bilateral torsion

4. EXPLANATION

B. Salvage rate drops to about 20% after 12 hours since onset. There is no doubt that longer periods of ischemia to the testicle result in higher rates of orchiectomy. Therefore, salvageability of the testicle is very time sensitive. Traditionally, it is thought that if the testicle is detorsed within 6 hours, there is a high chance of salvageability. This has been estimated to be as high as 97.2% in one systematic review (Mellick et al. 2017), but most studies range from 80% to 100% (Sharp et al. 2013; Mushtaq et al. 2003), choice A. Choice B is not a correct statement because after 12 hours the rate of salvage drops precipitously to approximately 50%, not 20%. After 24 hours since the onset of symptoms, the chance of complete salvage is low, between 0% and 20%, choice D. Interestingly, not all patients taken emergently to the operating room with a presumed diagnosis of testicular torsion are ultimately found to have the pathology, choice C.

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Keywords/Tags: Testicular infarction, salvage time, torsion, medical decision-making

5. EXPLANATION

B. These ultrasound findings are most likely benign. No specific further work up is necessary at this time. This ultrasound image shows a scrotolith or scrotal calculi (white arrow), also known as a scrotal pearl (see Figure 16.20). These are calcifications found within the scrotum, outside of the testicle, and can be incidental findings. Sonography will show a mobile, free floating, echogenic foci measuring up to 10 mm and with posterior acoustic shadowing. are mobile calcifications within the scrotum (Kühn et al. 2016). These are thought to result from torsion of the appendix epididymis or the appendix testis or from fibrous proliferation from previous inflammatory diseases of the scrotum. About 50% of these are associated with a hydrocele, which can improve identification (Kühn et al. 2016; Pearl and Hill 2007). Although these can result from inflammation within the scrotum, the finding of a scrotal calculi does not indicate an active infection (choice D). These findings are benign and no further work up is necessary (choice B). Unlike microlithiasis found within the testicle, there is no reported association with malignancy (choice A). These findings are unlikely to require further testing to confirm the diagnosis (choice C).

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Keywords/Tags: Testicular microlithiasis, malignancy, ultrasound screening

(a) (b)

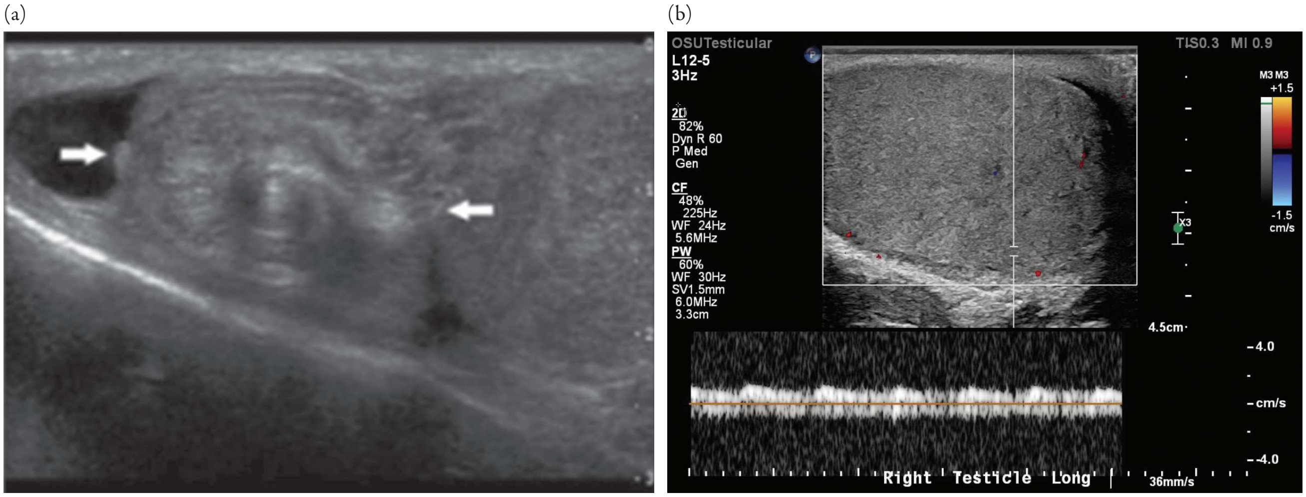

Figure 16.20 (a) **Whirlpool sign with twisting of spermatic chord.** Adapted from Figure 1 of McDowall J, Adam A, Gerber L, et al. The ultrasonographic "whirlpool sign" in testicular torsion: valuable tool or waste of valuable time? A systematic review and meta-analysis. *Emerg Radiol*. 2018;25(3):281–292. doi:10.1007/s10140-018-1579-x. (b) **Spectral Doppler of testicle showing decreased diastolic flow.**

6. EXPLANATION

D. The ultrasound is normal. Based on clinical history, intermittent testicular torsion is possible. Consult urology. Intermittent testicular torsion can be a difficult diagnosis. This occurs when the testicle torses and then spontaneously detorses prior to evaluation. Color Doppler alone has a reported sensitivity of 86%, specificity of 100% for testicular torsion so cases can be missed (Lin et al. 2007). There may not be evidence on exam and the ultrasound can demonstrate normal vascular flow (Bandarkar and Blask 2018). However, the patient is still at risk for retorsing, and, therefore, if this is suspected, the patient should not be discharged home without discussion with a urologist (choice A). Partial torsion (<360 degrees rotation) can also present with normal flow on ultrasound. There are other sonographic signs that are indicative of torsion. The whirlpool sign is a visualized twisting in the spermatic cord and is a specific sign for testicular torsion (Figure 16.20a, Video 16.1). The presence of an altered lie, redundant spermatic cord, enlarged epididymal-cord complex, and asymmetry on B-mode are other findings that may increase suspicion for testicular torsion (Bandarkar and Blask 2018). In addition, spectral waveform may show an increased resistive index with decreased or absent diastolic flow (Figure 16.20b) (Dogra et al. 2004). Directly after the torsion event, there may be an increase in blood flow to the affected testicle (Prando 2009). If there is continued suspicion for testicular torsion after a normal ultrasound, consultation with a urologist, observation, or serial ultrasounds may be warranted (choice D). The ultrasound shown in the case shows normal and symmetric flow to the bilateral testis (choice B). The flow is not excessive and the history and exam would not correlate with a diagnosis of orchitis (choice C).

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Keywords/Tags: Intermittent torsion, partial torsion, false negative, Doppler flow, management

7. EXPLANATION

C. A spherical appendage superior to the right testicle with no blood flow. This patient has a torsed right testicular appendage. This will present as testicular pain that can be difficult to differentiate clinically from testicular torsion. The appendix testis is a remnant of the Mullerian duct located on the superior aspect of the testicle (Fujita et al. 2017). Clinically, one may observe a "blue dot sign" and/or a palpable nodule on upper pole of testis on physical examination. It is key to distinguish torsion of the appendix testis from testicular torsion, because the latter requires surgical management whereas torsion of the appendix is treated symptomatically and does not lead to adverse long-term effects. Ultrasound of the testicle does not show decreased testicular blood flow in torsion of the appendix, in contrast with testicular torsion (Fujita et al. 2017) (choice A). Ultrasound imaging in torsion of the appendix (Figure 16.21) may demonstrate a 5 mm or larger, spherical or round appendage with heterogeneous echogenicity with small cystic structures, increased periappendiceal blood flow, and no blood flow within the torsed appendage (choices C, D) (Lev et al. 2015). Scrotal skin thickening and peri-testicular fluid can also be seen. Together the findings can appear similarly to epididymitis on ultrasound. Both will have hyperemia of the epididymis on the affected side (choice B) and therefore identifying the avascular appendix testis is key to sonographic diagnosis (Bandarkar and Blask 2018). Treatment of torsion of the appendix testis includes nonsteroidal anti-inflammatory drugs, scrotal support, and outpatient Urology referral as needed for persistent pain or parental concern (Fujita et al. 2017).

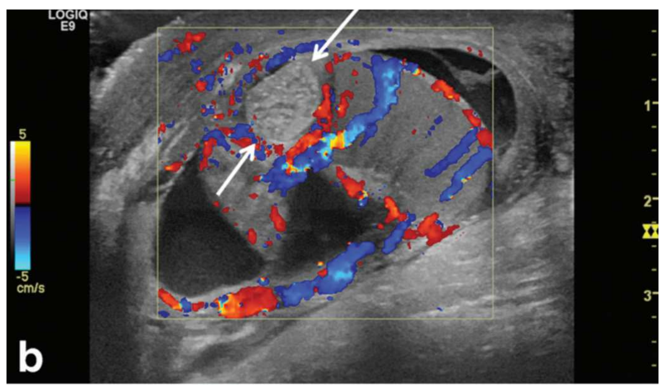

Figure 16.21 **Torsed testicular appendage (white arrows).** It is >5 mm, spherical in shape, echogenic, has increased periappendiceal blood flow, and has no blood flow within the torsed appendage. Adapted from Figure 8b of Bandarkar AN, Blask AR. Testicular torsion with preserved flow: key sonographic features and value-added approach to diagnosis. *Pediatr Radiol*. 2018;48(5):735–744. doi:10.1007/s00247-018-4093-0.

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Keywords/Tags: Torsion of the appendix testis, testicular torsion, epididymitis

8. EXPLANATION

A. Epididymo-orchitis. Epididymitis is the most common cause of painful scrotal swelling in adults. It causes include viral infection, bacterial infection, trauma, autoimmune disorders, or medication effects (Banyra and Shulyak 2012). Sexually transmitted diseases are a common cause. Although the epididymis is often involved first, the process can spread to affect the testis. This occurs in approximately 33% of epididymitis (Wittenberg et al. 2006). The sonographic findings of epididymitis include an enlarged hypoechoic epididymis with increased Doppler flow (Pearl and Hill 2007; Figure 16.5a). In addition, hydrocele, pyocele, and scrotal skin thickening can be present but are not specific. In epididymo-orchitis, the involvement of the testicle can be focal or diffuse. This may appear as multiple hypoechoic lesions in the testicle. Color Doppler usually shows asymmetrically increased blood flow to the testis compared with the normal contralateral testis (Figure 16.5b). Calcifications can be seen chronic orchitis. Testicular abscess can is also associated with acute epididymo-orchitis. Sonographically this would appear as an enlarged testicle containing a complex fluid collection. Color Doppler has a sensitivity of almost 100% for acute inflammation (Pearl and Hill 2007; Kühn et al. 2016). The treatment of acute epididymo-orchitis includes antibiotics, pain control, supportive care, and in refractory cases surgery (Banyra and Shulyak 2012). Torsion of the appendix testis can appear similarly to epididymitis since both can exhibit hyperemia of the epididymis; however, epididymitis more commonly has enlargement of the epididymis and will not have an avascular appendix visualized (choice B). Testicular torsion (choice C) generally shows decreased vascular flow, although directly after detorsion it may have increased blood flow. Torsion will not show other signs of epididymo-orchitis. Testicular cysts (choice D) may appear similar to testicular abscess but would not have the other findings of inflammation seen in epididymo-orchitis.

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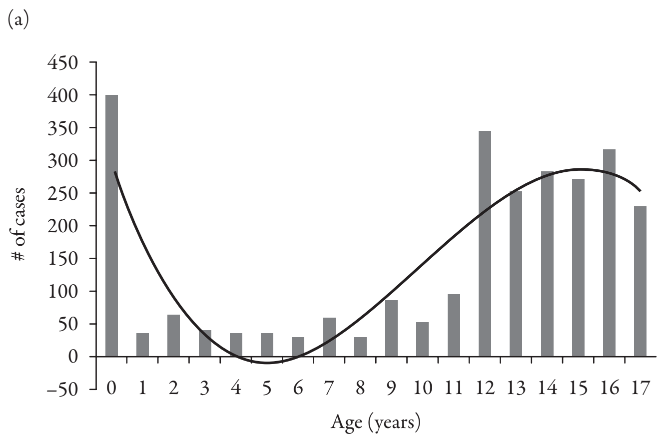
Keywords/Tags: Epididymo-orchitis, epididymitis, orchitis, color Doppler

9. EXPLANATION

B. 12-year-old male. This patient has testicular torsion based on the history, exam, and sonographic findings. Testicular torsion has an incidence of 3.8 per 100,000 males less than age 18. Although testicular torsion can occur at any age (choices A, C, D), it has a bimodal distribution with peaks at age 1 month and at age 12 (choice B) (Zhao 2011); see Figure 16.22a. The latter is due to the rapid growth



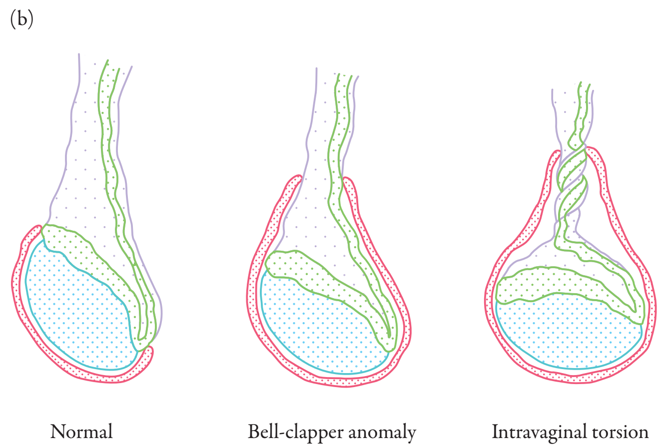


Figure 16.22 (a) **Age distribution of testicular torsion.** Adapted from Figure 1 of Zhao LC, Lautz TB, Meeks JJ, Maizels M. Pediatric testicular torsion epidemiology using a national database: incidence, risk of orchiectomy and possible measures toward improving the quality of care. *J Urol*. 2011;186(5):2009–2013. doi:10.1016/j.juro.2011.07.024. (b) **Normal testicle, bell-clapper anomaly, and intravaginal torsion.** Blue = testis. Green = epididymis. Purple = spermatic cord and vessels. Red = tunica vaginalis. Adapted from Figure 1 of Bandarkar AN, Blask AR. Testicular torsion with preserved flow: key sonographic features and value-added approach to diagnosis. *Pediatr Radiol*. 2018;48(5):735-744. doi:10.1007/s00247-018-4093-0.

of the testicle during puberty, and 42% of patients may require orchiectomy. Testicular torsion can be extravaginal or intravaginal, depending on whether or not the torsion occurs within the tunica vaginalis (Bandarkar and Blask 2018). Extravaginal torsion is more common in newborns, especially if premature, but it also can occur antenatally. Intravaginal torsion can occur at any age, but is commonly diagnosed in males ages 12 to 18 years old. The bell-clapper anomaly, occurring in approximately 12% of testes, is an anatomic anomaly in which the tunica vaginalis is not attached to the epididymis posteriorly, allowing the testis to hang freely in the intravaginal space (Figure 16.22b). This anomaly generally appears to have a more horizontal lie at baseline. This is a primary risk factor for intravaginal testicular torsion (Sharp et al. 2013).

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Keywords/Tags: Testicular torsion, bell clapper, demographics, risk factors

10. EXPLANATION

A. Ultrasound. This patient has sustained testicular trauma. After assessing for life-threatening concurrent intra-abdominal injury, the diagnostics should focus on evaluating for traumatic injuries within the scrotum. Ultrasound is a fast and accurate means to diagnose the majority of traumatic injuries to the scrotum and is therefore the first line imaging modality. Ultrasound can identify hematoma, testicular fracture, and penile fracture (McAdams and Del Gaizo 2018). There is variability in the reported accuracies based on pathology and study. For testicular rupture, the sensitivity is 100% and specificity 93.5%, although reported accuracies vary based on findings and the study performed (Rao and Arjun 2012). MRI (choice B) is a good second line imaging modality that was found to be 100% accurate for testicular rupture in one small study. MRI may help with characterization of soft tissue injuries (Wang et al. 2017). CT (choice C) has virtually no role in the diagnosis of traumatic testicular pathology, as ultrasound and MRI evaluate the injuries more accurately. Nevertheless, some injuries can be diagnosed on CT imaging that is indicated for other trauma. Hematomas on ultrasound can appear intra- or extra-testicular. Acute blood may appear echogenic (Adlan and Freeman 2014). Hydroceles occur in up to 25% of patients with major trauma and appear as anechoic fluid collections that separate the layers of the tunica vaginalis. Penile fractures on ultrasound appears as a defect along the tunica albuginea with possible hematoma deep to the skin or Buck's fascia. Testicular fracture appears as a linear hypoechoic band through the testicle, with the shape of the testicle maintained. In testicular rupture, the echogenic tunica albuginea is broken, leading to poorly defined testicular margins with hemorrhage and extrusion of the testicular contents into the scrotum. Color Doppler should be used to assess for any disruption of vascular supply to the testis. Contrast enhanced ultrasound has a role in determining testicular perfusion after trauma (Wang et al. 2017; Adlan and Freeman 2014). A urinalysis (choice D) is not definitive for diagnosing scrotal trauma.

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Keywords/Tags: Trauma, testicle, imaging, diagnosis

11. EXPLANATION

D. Further testing is needed to rule out malignancy. The image in this case shows increased vascularity to one testicle. This is a finding that can be found in both inflammatory conditions (such as orchitis) and malignancy. Color Doppler alone cannot differentiate malignancy from inflammatory hypervascularity. Given this patient's age and the chronicity of the complaint, one cannot disregard the possibility of malignancy in favor of infection (choice A). Ultrasound is used to characterize nonpalpable testicular nodules (Rocher et al. 2016). Simple intratesticular cysts <0.5 cm are usually benign whereas larger lesions, hypoechoic nodules, and grouped microliths are suggestive of malignancy. Infiltrative malignancies such as testicular lymphoma may not distort the architecture of the testicle but may appear only as hypoechoic lesions with a hypervascular appearance (choice C; Bertolotto et al. 2015). Therefore, it may be difficult to sonographically distinguish this from orchitis and other inflammatory conditions. Although hypervascularity of both the epididymis and testicle may more commonly

represent epididymo-orchitis, malignancy can present with the same sonographic findings, including enlargement of the epididymis (Ishigami et al. 2004). Similarly, it has been thought that testicular hypervascularity without concurrent epididymal hypervascularity would more likely indicate a malignancy than isolated orchitis. The sonographer should be aware of this mimic and maintain a high index of suspicion for malignancy when faced with these findings. Asymmetric hypervascularity is not a normal variant and should suggest pathology (choice B).

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Keywords/Tags: Malignancy, lymphoma, leukemia, tumor, Doppler, infection, diagnosis

12. EXPLANATION

A. Complete testicular ischemia. The ultrasound in the case (Figure 16.7) shows testicular contour deformity and disrupted tunica albuginea (arrows) with focal devitalized edematous testicular parenchyma (asterisk) and a hematocele. Blunt scrotal trauma is the most common mechanism for testicular rupture. The clinical exam can be difficult due to pain and swelling and therefore sonography can be useful for rapid identification of pathology (Adlan and Freeman 2014). Testicular rupture is defined as a disruption of the tunica vaginalis surrounding the testicle. At times the disrupted tunica vaginalis can itself be visualized, although this can be difficult (only 50% in one case series; Fenton et al. 2016). The findings on ultrasound include change in contour of the testicle (choice D) and a heterogeneous echotexture of the testis indicating intra-testicular hematoma. Hematoceles are also common (choice C) (Micallef et al. 2001). Testicular fracture, a disruption of the testicular parenchyma, can occur with or without rupture. In testicular fracture, the ultrasound will show an avascular fracture line through the testis (choice B). The concern in these cases is disruption of blood flow to the testis from the injury. Color Doppler should be used to assess for the absence of blood flow to the testicle; the patient in this case had partial preserved blood flow and has not developed complete testicular ischemia (choice A). Timely diagnosis is crucial as these patients generally require operative repair for testicular salvage. In the case of testicular rupture, the salvage rate drops from 90% to 45% after 72 hours (Fenton et al. 2016). Regarding the accuracy of ultrasound, the presence of both a heterogeneous testicle and a loss of normal testicular contour was found to be 100% sensitive and 93.5% specific for testicular rupture (Buckley and McAninch 2006).

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Keywords/Tags: Testicular fracture, testicular rupture, testicular rupture

13. EXPLANATION

D. This is a sensitive finding. The ultrasound image of this patient shows a testicular fracture (choice B). This is defined as a break in the testicular parenchyma. It can be associated with testicular rupture (Bhatt and Dogra 2008). The sonographic finding is that of a fracture line, seen as a linear hypoechoic area within the testis. The fracture line will not have Doppler flow (choice A), although Doppler should be used to assess the vascularity of the surrounding testicular parenchyma, which can indicate its salvageability. An associated hematocele or hematoma may be present (Rao and Arjun 2012). Unfortunately, the fracture line is an insensitive finding, appearing in only approximately 17% of cases. It may not be visible due to filling with isoechoic hematoma. Of note, 50% of males have a transmediastinal artery that will transect the testicle but will have Doppler flow (Figure 16.23). Other injuries associated with blunt trauma to the scrotum include testicular torsion, testicular dislocation, hematomas, intratesticular pseudoaneurysm, traumatic epididymitis, epididymal fracture or rupture, and spermatic cord hematoma (Bhatt and Dogra 2008). Ultrasound has variable accuracy in detecting these pathologies. There is little reported on using point-of-care ultrasound to diagnose traumatic scrotal injuries, although case reports confirm it can expedite care when used appropriately (Indra et al. 2017).

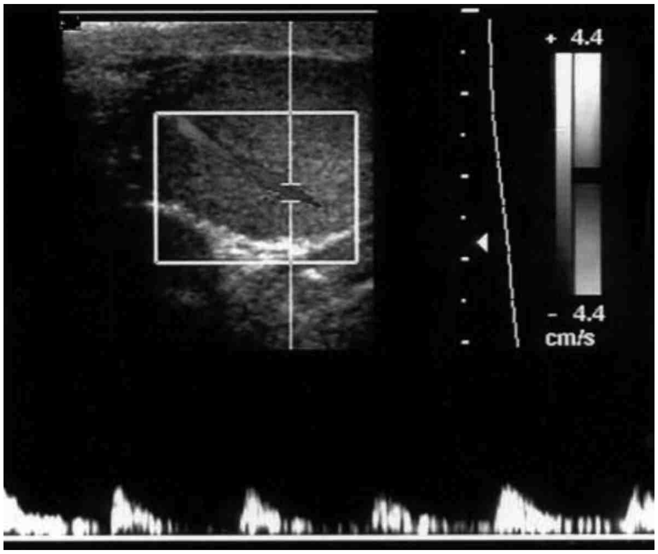

Figure 16.23 **Transmedial artery with Doppler flow.** This can sometimes be mistaken for a testicular fracture. Adapted from Figure 3, Dogra VS, Rubens DJ, Gottlieb RH, Bhatt S. Torsion and beyond: new twists in spectral Doppler evaluation of the scrotum. *J Ultrasound Med*. 2004;23(8):1077–1085.

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Keywords/Tags: Testicular fracture, testicular rupture, diagnosis, ultrasound, trauma, hematoma

14. EXPLANATION

B. Heterogenous echogenicity of the left testicular and epididymis. Fournier's gangrene is an aggressive polymicrobial necrotizing fasciitis affecting the perineal, perianal, or genital regions with high morbidity and mortality. It can often present as scrotal pain and can be difficult to distinguish from a dermatitis or simple cellulitis (Kim and Kendall 2013). The diagnosis is made clinically; however, both CT and ultrasound can be helpful for establishing the diagnosis. Ultrasound performed at the bedside can be particularly helpful in an unstable patient who cannot travel to radiology (Kube et al. 2012). The sonographic findings include a thickened edematous scrotal wall, unilateral or bilateral peritesticular fluid, and air in the scrotal wall (Figure 16.24a) or surrounding soft tissue that appears as small hyperechoic foci with a "dirty" posterior shadow (choices A and D; Kim and Kendall 2013) (Figure 16.24b, Video 16.2). There is some evidence that sonographically identified gas may precede palpable crepitus. It is important to distinguish the gas from a necrotizing infection from bowel gas present in an inguinal hernia. "Cobblestoning" (choice C) refers to increased anechoic fluid within the superficial soft tissue and is associated with cellulitis, as well as other disorders leading to subcutaneous edema. There may also be increased vascular flow to the scrotal wall (Kühn et al. 2016). Generally, the testes and epididymides themselves have a normal appearance on ultrasound (choice B). Rapid diagnosis by ultrasound allows for early recognition which can expedite treatment including broad spectrum antibiotics and surgical debridement. CT has a role in making the diagnosis and even if the diagnosis has been established, may assist in operative planning (Weatherspoon et al. 2017); see Figure 16.24c. However, given the rapid progression of this disease, no unnecessary delays should impede definitive management.

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Keywords/Tags: Infection, cellulitis, Fournier's gangrene, necrotizing infection

15. EXPLANATION

D. Varicocele. The ultrasound image (Figure 16.9), shows a varicocele with several tubular structures greater than 3 mm (panels A and B) with markedly increased vascular flow on color Doppler evaluation on resting (panels C and D). This occurs in up to 15% of adult males and can present as a dull ache or pain in the scrotal area (Meacham et al. 1994). Varicoceles are abnormal dilations of the pampiniform plexus that can be associated with pain and infertility. Primary varicoceles result from venous reflux from the internal spermatic vein due to incompetent valves and are more common on the left side due to the 90-degree angle with which this vein drains into the left renal vein. Secondary varicoceles can result from hydronephrosis, hepatic cirrhosis, abdominal neoplasms, compression of the left renal vein, or any other process that increases the pressure of the testicular veins (Pauroso et al. 2011). Varicoceles

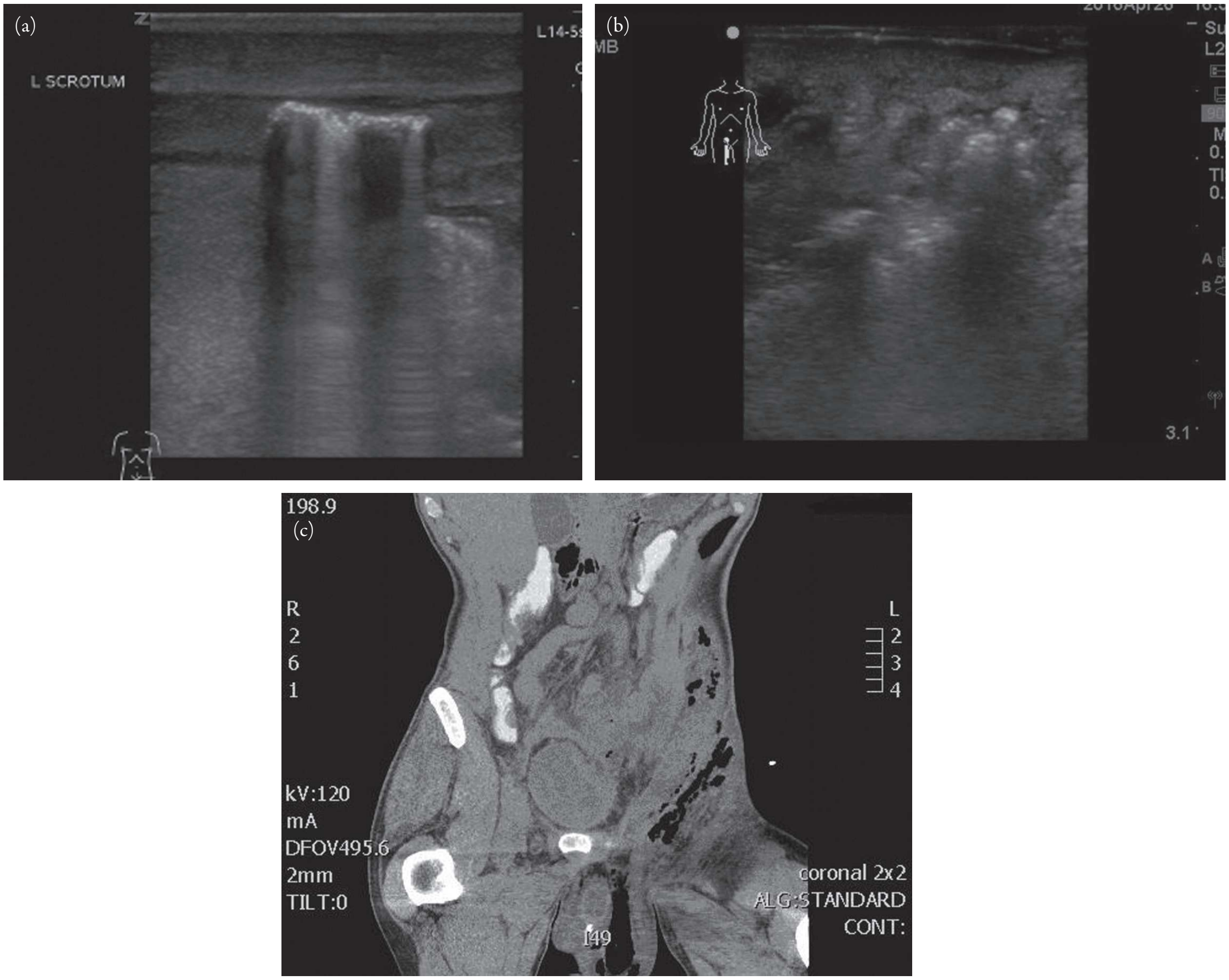

Figure 16.24 (a) **Air in the scrotal wall**. (b) **Scrotal edema with "dirty" shadowing from subcutaneous emphysema**. (c) **CT scan showing Fournier's gangrene with extensive subcutaneous emphysema**.

are clinically seen as a palpable mass within the scrotum, described as similar to a "bag of worms." On ultrasound, varicoceles appear as a multiple, elongated, serpentine, anechoic, tubular structures with diameters >2 mm (Kühn et al. 2016). Evaluation in the standing position or with Valsalva maneuver is often helpful to observe additional distention of the veins, and color Doppler should confirm venous blood flow. Valsalva may demonstrate flow reversal on color Doppler. Color Doppler ultrasound is nearly 100% sensitive and specific for diagnosing varicoceles (Pauroso et al. 2011). Blood flow may be too low for detection at rest but will become evident during Valsalva. Color Doppler can also be used for grading of varicoceles. In general, higher grades are determined by longer durations of venous reflux during a Valsalva maneuver. A large or acute varicocele can be secondary to obstruction of the spermatic vein by a retroperitoneal or hilar mass, so sonographic evaluation of the ipsilateral kidney may be indicated. Since right-sided primary varicoceles only occur 15% of the time, this finding often prompts workup for a secondary cause such as an obstruction of the IVC (Pauroso et al. 2011). Epididymitis (choice A) will show enlargement and hyperemia of the epididymis. Hydroceles (choice B) will appear as anechoic fluid collections. Testicular tumors (choice C) may have a variety of appearances but generally show a hypoechoic mass within the testicle with or without color Doppler flow.

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Keywords/Tags: Varicocele, color Doppler

16. EXPLANATION

B. Testicular torsion. This patient presented with blunt scrotal trauma. Figure 16.10 shows testicular torsion of the left testicle. The right testicle is homogeneous in echotexture and morphologically normal in appearance. There is an abnormal lie of the left testis with swirling of the spermatic cord (whirlpool sign) and diminished flow seen on color and power Doppler interrogation. Testicular torsion should always be a consideration in the event of blunt scrotal trauma, because along with testicular rupture and fracture, it is an indication for emergent operative management (Fenton et al. 2016). It is estimated that 5% to 8% of torsion is precipitated by trauma (Bhatt and Blask 2008). This may be due to increased testicular mobility from a bell clapper deformity or from rotation during the sudden forceful contraction of the cremasteric muscle. The whirlpool sign is sonographic visualization of the vascular twisting of the spermatic cord. This is thought to be the most specific sign of testicular torsion and, unlike reduced testicular color Doppler, will be evident even without decreased blood flow to the testicle. In one multicenter study, twisting of the spermatic cord was found to be 99% specific and 97.3% sensitive (Kalfa et al. 2007). In comparison, looking for reduced color flow Doppler had only a sensitivity of 79% for detecting testicular torsion. Other sonographic findings of testicular torsion include homogeneous testicular parenchyma, the presence of an altered lie, redundant spermatic cord, and enlarged epididymal-cord complex (Bandarkar and Blask 2018). Traumatic epididymitis (choice A) is possible but would not present with this appearance on ultrasound. Testicular rupture (choice C) and hematocele (choice D) are also concerns after blunt scrotal trauma, but these would have distinct sonographic findings not seen here.

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Keywords/Tags: Trauma, testicular torsion, whirlpool sign, color Doppler

17. EXPLANATION

D. Clinician-performed ultrasound examinations for testicular torsion is accurate. The patient in this case has testicular torsion and the question is whether or not there is utility to performing a clinician performed or "point-of-care" study. Ultrasound is clearly the diagnosis of choice when concerned for testicular torsion in the ED. The physical exam is not sufficient to rule out this condition (choice B). Comprehensive studies performed by a sonographer at triage in the ED have shown to be accurate with a 94% sensitivity and 96% specificity for testicular torsion (Yagil et al. 2010). It is true that this is a time-sensitive condition, with the best rates of salvage when treatment occurs within 6 hours (Wright and Hoffmann 2015). Therefore, there should be no delays in obtaining definitive operative treatment for the patient when the diagnosis is clear (choice A). However, oftentimes, as in this case, there is suspicion but not a high enough concern to take the patient directly to the operating room without imaging, which may impose unnecessary risk. In this case, ultrasound should be performed. If comprehensive ultrasound is available immediately, that may be the optimal choice; however, in all other cases, point-of-care ultrasound can be performed and is accurate for the diagnosis of testicular torsion (choice D). Almost all point-of-care machines are capable of performing color Doppler and power Doppler, which is used for the exam (choice C). Unfortunately, there are few studies regarding the use of point-of-care ultrasound for scrotal pathologies, both in adults and pediatrics. Case series show that emergency physicians have the potential to expedite the diagnosis and treatment for this pathology using ultrasound (Blaivas et al. 2000). The best evidence regarding accuracy is limited to a single retrospective study of 36 patients who received an ultrasound for acute scrotal pain (Blaivas et al. 2001). Compared to radiology studies or surgical confirmation, the ED studies had overall 95% sensitivity and 94% specificity. No cases of testicular torsion were missed. Clearly more research is needed, but given this limited evidence and the ability to obtain rapid information with bedside ultrasound, it should be performed when it can potentially hasten the diagnosis of testicular torsion.

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Keywords/Tags: Testicular torsion, point of care, color Doppler, emergency physician

18. EXPLANATION

C. Consult urology for surgical management of testicular torsion. Testicular torsion can be incomplete or intermittent if the cord is twisted less than 360 degrees. There may still be flow to the testicle, but the testicle is not receiving the normal amount of blood supply (DeMauro and Horrow 2008). It may be falsely reassuring to see blood flow within the symptomatic testicle. This can occur in incomplete torsion because the vasculature it not completely occluded; however, the clinician should be concerned with any asymmetry in the Doppler flow. There may be only arterial flow with the absence of the lower pressure venous flow. Subtle differences can be seen in the arterial spectral Doppler waveform such as decreased diastolic velocity or diastolic reversal, or an increased resistive index (Bandarkar and Blask 2018; Dogra et al. 2004); see Figure 16.25a (normal) and Figure 16.25b (abnormal). The whirlpool sign is a visualized twisting in the spermatic cord and can be seen even in incomplete torsion. On gray-scale B-mode imaging, the twisted cord can appear as an edematous enlarged epididymis, leading to misdiagnosis of epididymitis and delays in treatment (DeMauro and Horrow 2008). The presence of an altered lie (Figure 16.25c), redundant spermatic cord, enlarged epididymal-cord complex, and asymmetry on B-mode are other findings that may increase suspicion for testicular torsion (Bandarkar and Blask 2018). Furthermore, this patient's history and exam findings are consistent with testicular torsion, and if surgery is delayed, the testicle may completely torse in the future and will thus be unsalvageable. Urology consult (choice C) is the most appropriate next step. Delays caused by misdiagnosis (choice A), observation (choice B), or nonsurgical management (choice D) can also lead to a decreased rate of testicular salvage.

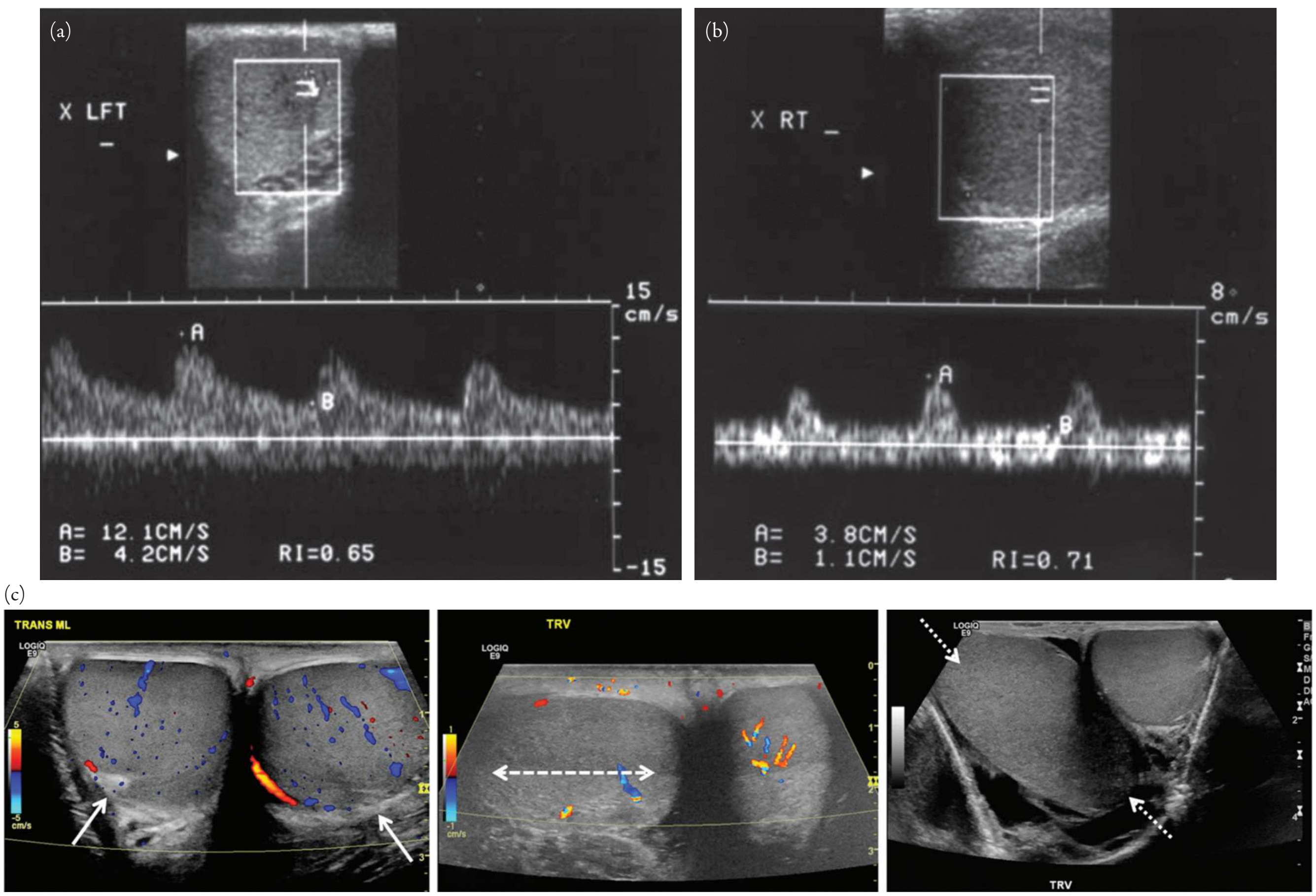

Figure 16.25 (a) **Normal flow in the testis.** (b) **Increased resistive index with reduced diastolic flow in a patient with testicular torsion.** Adapted from Figure 4 of Dogra VS, Rubens DJ, Gottlieb RH, Bhatt S. Torsion and beyond: new twists in spectral Doppler evaluation of the scrotum. *J Ultrasound Med.* 2004;23(8):1077–1085. (c) **Testicular lie.** (A) Color Doppler transverse ultrasound (US) image of normal vertical lie with the mediastinum testis (arrows) directed posterolaterally. (B) Color Doppler transverse US image of both testes demonstrating abnormal horizontal lie of the right testis (perforated arrow) with slightly decreased intratesticular flow compared to the normal left side. (C) Grayscale transverse US image demonstrating abnormal oblique lie of the right testis (dotted arrows), which is oriented diagonally compared to the normal left side. Adapted from Figure 5 of Bandarkar AN, Blask AR. Testicular torsion with preserved flow: key sonographic features and value-added approach to diagnosis. *Pediatr Radiol.* 2018;48(5):735–744. doi:10.1007/s00247-018-4093-0.

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Keywords/Tags: Incomplete, partial testicular torsion, color Doppler, spectral Doppler

19. EXPLANATION

A. Torsion of the appendix testis. This patient has granulomatous orchitis. The ultrasound image reveals a uniformly hypoechoic, slightly enlarged left testicle with normal flow on color Doppler. Granulomatous orchitis can be caused by an infection or can be idiopathic. Mycobacterium tuberculosis is the most common infectious etiology, likely extending from an infection in the epididymis. This disease tends to present in the sixth or seventh decade of life with an enlarged testicle with or without palpable mass, pain of varying intensity, surrounding skin changes, and fistula (Mogensen and Nino-Murcia 2005). However, it is important to note that the sonographic appearance may appear similarly to genitourinary tuberculosis, seminoma (choice C), lymphoma (choice D), or leukocytic infiltrates. Sonographic features such as a homogenous echotexture, enlarged epididymis, scrotal wall thickening, and large volume or peritesticular fluid point toward a benign process, but no sonographic finding is absolute in distinguishing (Mogensen and Nino-Murcia 2005). There are reports of malignancies that can mimic infectious processes with enlargement and hyperemia of the epididymis and testis (Ishigami et al. 2004). This condition may require orchiectomy for definitive diagnosis. Torsion of the appendix testis (choice A) would not fit the clinical scenario described. Although it can also present with hyperemia of the epididymis, it can usually be distinguished from other etiologies by sonographic findings of a 5 mm or larger, spherical or round appendage with heterogeneous echogenicity with small cystic structures, increased periappendiceal blood flow, and no blood flow within the torsed appendage (Lev et al. 2015).

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Keywords/Tags: Tumor, mass, malignancy, granulomatous orchitis, leukemia, lymphoma, torsion of the appendix testis

20. EXPLANATION

C. Reducing the hernia with the ultrasound probe after Valsalva. Ultrasound can assist in the diagnosis of abdominal and inguinal hernias both by aiding diagnosis and potentially guiding reduction. Ultrasound allows for differentiating a hernia from other causes of abdominal or groin masses and can determine whether the hernia is incarcerated or strangulated (Siadecki et al. 2014). Oftentimes an indirect hernia can be visualized within the scrotum (Figure 16.26, Video 16.3). A hernia will appear as a hyperechoic, sac-like structure with distinct boundaries. Strangulation of bowel can be suggested by findings of lack of peristalsis, bowel wall edema, and lack of color Doppler flow. For abdominal hernias, a defect in the fascial wall can be found deep to the hernia. Since this defect is not always directly under the mass of the hernia sac, ultrasound can guide reduction by direction the force of the reduction toward the fascial defect (Siadecki et al. 2014). A study by Chen et al. (2005) showed that using ultrasound to reduce incarcerated inguinal hernias resulted in less emergency surgery for hernia reduction, but the difference between groups was not statistically significant. A high resolution (minimum 7–12 MHz) transducer is employed when performing ultrasound for inguinal hernia (choice A). Having the patient Valsalva during the study may increase visibility of the hernia. One

Figure 16.26 **Inguinal hernia in scrotum.**

suggested scanning method is to begin finding the spermatic cord at the pubis and then sweep the transducer superiorly toward the deep ring of the inguinal canal. This will visualize the entire inguinal canal. This method, as opposed to scanning in the opposite direction (choice D), eliminates the need to identify the inferior epigastric arteries to find the deep ring and identifies the spermatic cord at the onset which otherwise can be mistaken for an indirect hernia. Reducing the hernia with the ultrasound probe can be helpful to confirm the diagnosis (choice C). Asking the patient to cough (choice B) will increase intra-abdominal pressure but can make the hernia harder to track (Jansen and Yielder 2018).

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Keywords/Tags: Hernia, abdominal, inguinal, technique, acquisition

21. EXPLANATION

A. Hydrocele. Hydrocele is an abnormal collection of simple fluid between the visceral and parietal layers of the tunica vaginalis (Aso et al. 2005). This is the most common cause of painless scrotal swelling and can be congenital or acquired (Kühn et al. 2016). Congenital hydroceles are due to the accumulation of peritoneal fluid through an abnormally patent processus vaginalis. Acquired hydroceles can be due to infection, torsion, trauma, or tumors, or it can be idiopathic. It is normal to have a small amount of fluid between these layers. On ultrasound, a hydrocele appears as an anechoic fluid collection surrounding the anterolateral aspects of the testicle. Occasionally there can be internal echoes within the fluid. The testicle is usually normal in appearance. Hematoceles (choice B) are collections of blood within the same space in the tunica vaginalis. They can be related to trauma and will appear echogenic in the acute phase. Chronically, they can appear hypoechoic and can have septations (Kühn et al. 2016). Pyoceles (choice C) are collection of pus between the layers of the tunica vaginalis and can accompany scrotal infections. Epididymal cysts (choice D) and spermatoceles are the 2 types of extratesticular cysts. These are commonly incidental findings and can appear similarly on ultrasound as circular anechoic areas near the epididymis (Pearl and Hill 2007). Spermatoceles can be related to prior trauma or infection. These are more common than epididymal cysts and arise from the epididymal head. Epididymal cysts can arise throughout the epididymis (Figure 16.27).

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Keywords/Tags: Hydrocele, hematocele, pyocele, epididymal cyst, spermatocele

22. EXPLANATION

B. Microlithiasis. Testicular microcalcifications are 1 to 3 mm non-shadowing calcifications found in the testicle (Kühn et al. 2016). These are usually incidental findings. These occur in 5% of healthy males between the ages of 17 and 35 (Peterson et al. 2001). The calcifications are bright and fine. They tend to be hyperechoic and uniform in size and distribution, although they can be isolated to one area. These sonographic features are fairly specific and appear distinct from seminoma and lymphoma (choices A and C). These are also not considered normal findings (choice D). The etiology of microlithiasis is unknown. Traditionally, these lesions are thought to be premalignant and can be associated with testicular cancer as well as infertility (Yee et al. 2011). A recent systematic review of the literature suggested that in healthy patients without other risk factors for malignancy, there may be no additional cancer risk above the general population, but this is still uncertain (Leblanc et al. 2018). Diligent self-exams and occasionally annual ultrasound may be still recommended so urology follow-up is warranted. In patients with risk factors for testicular cancer or in patients who are symptomatic, further workup can be indicated.

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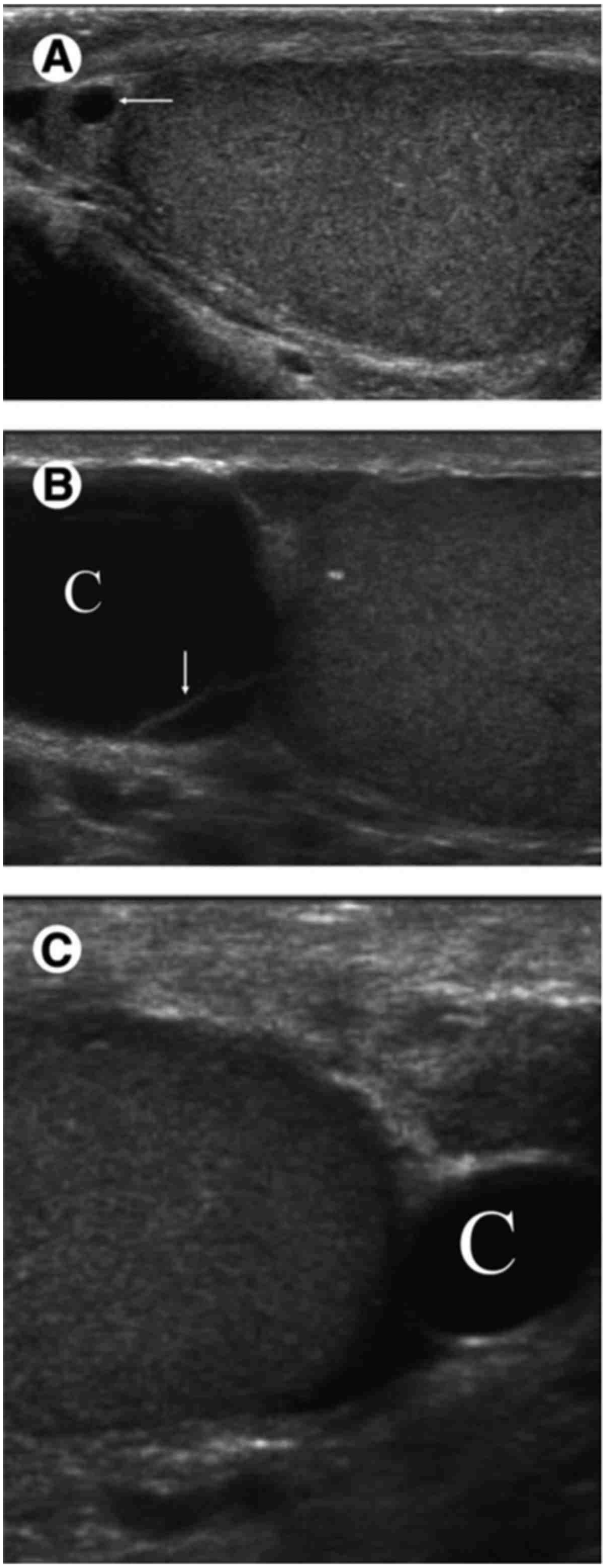

Figure 16.27 **Epididymal cysts.** (a) Small epididymal cyst (arrow). (b) Large epididymal cyst (labeled C) with a septum (arrow). (c) Epididymal tail cyst (labeled C). Adapted from Figure 20 of Pearl MS, Hill MC. Ultrasound of the scrotum. *Semin Ultrasound CT MR*. 2007;28(4):225–248. doi:10.1053/j.sult.2007.05.001.

Keywords/Tags: Testicular microlithiasis, scrotal pearls, malignancy, ultrasound screening

23. EXPLANATION

D. Testicular tumor. Henoch-Schonlein purpura (HSP) is a systemic vasculitis disease in which the testes are affected in 15% to 37% of patients (Aso et al. 2005). Scrotal findings may be the first indication of the disease. Clinically, this can present with scrotal rash, edema, and scrotal pain (Modi et al. 2016). In some cases, it may mimic testicular torsion. This may manifest with findings of bilateral epididymal enlargement (choice A), scrotal wall thickening (choice B), and reactive hydroceles (choice C). This can be similar in appearance to epididymitis and therefore this is should be a consideration whenever these findings present bilaterally. Testicular tumor (choice D) is not commonly associated with HSP. Other systemic diseases with common scrotal involvement include acute hemorrhagic edema of infancy, acute idiopathic scrotal edema of possible allergic origin, and congenital adrenal hyperplasia (Aso et al. 2005).

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Keywords/Tags: Henoch-Schonlein purpura, systemic disease, torsion mimic, diagnosis

24. EXPLANATION

A. Soft tissue edema and rupture of tunica albuginea. Penile fracture is a urologic emergency defined as the rupture of the corpus cavernosum. Penile fracture presents with soft tissue edema, hematoma, and deformity of the penis. The diagnosis can be made clinically, but ultrasound and MRI can also be used to confirm the diagnosis (Koifman et al. 2010). The penis can be assessed using a high-frequency linear probe, with the penis positioned on the abdomen. A standoff pad may facilitate imaging. The primary finding on ultrasound is the disruption of the tunica albuginea, although soft tissue swelling and hematoma may also be seen (Figure 16.28). The tunica albuginea is normally a thin echogenic line and a discontinuity in this line is concerning for a penile fracture (McAdams and Del Gaizo 2018). MRI offers better soft-tissue contrast and spatial resolution

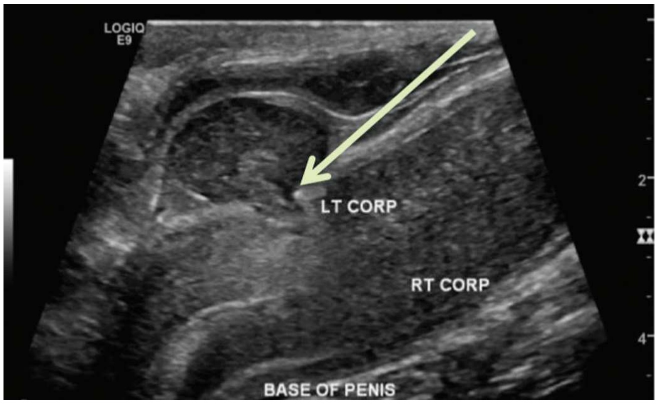

Figure 16.28 **Focal defect along the dorsal tunica albuginea with herniation of a portion of the corpora cavernosa (arrow), consistent with penile fracture.** LT CORP = left corpus cavernosa; RT CORP = right corpus cavernosa. Adapted from Figure 9 of McAdams CR, Del Gaizo AJ. The utility of scrotal ultrasonography in the emergent setting: beyond epididymitis versus torsion. *Emerg Radiol*. 2018;33(1):721. doi:10.1007/s10140-018-1606-y.

but may not always be available. Ultrasound will not be able to rule out a urethral injury and therefore retrograde urethrocystogram may also be necessary. Doppler flow should be normal in most cases of penile fracture (choice A). No urethral dilation (choice C) or subcutaneous air (choice D) is likely to be seen. Data regarding the accuracy of ultrasound for this diagnosis is currently nonexistent with the literature primarily consisting of case reports (Nomura and Sierzenski 2010). Theoretically, ultrasound could be beneficial in the cases that are not clinically obvious, as it is more rapid and available than MRI. Patients with penile fractures generally require surgical repair, and therefore ultrasound may help expedite this treatment.

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Keywords/Tags: Penile fracture, trauma, MRI, tunica albuginea

25. EXPLANATION

B. Mediastinum testis; indicates normal finding. Although this patient's history is concerning for an infectious etiology of his testicular pain, the image should be recognized as normal anatomy of the testicle. The mediastinum testis is an echogenic band that runs across the posteromedial aspect of the testicle. It is an extension of the tunica albuginea (Kühn et al. 2016). Fibrous septa can be seen coming from the mediastinum dividing the testis into lobules (Pearl and Hill 2007). In contrast to the mediastinum testis, a fracture line, representing a disruption in the testicular parenchyma, will be anechoic (choice A). The mediastinum testis is recognizable by its sonographic appearance and position and should not be confused with heterogeneous testicular parenchyma (choice C) or a testicular mass (choice D). Familiarity with normal anatomy including the striated appearance of the testicle, the epididymitis, and the appendix testis is an important prerequisite for performing ultrasound of the scrotum.

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Keywords/Tags: Testicle, normal anatomy, image acquisition, mediastinum testis

26. EXPLANATION

C. Refer for close outpatient follow-up. This ultrasound shows a testicular tumor, specifically a seminoma with a heterogenous mass (arrow), with vascular flow on color Doppler (Figure 16.16). Intratesticular tumors are 90% to 95% malignant as compared to extratesticular masses which are more likely benign (Pearl and Hill 2007). Given the high rate of malignancy, this finding on ultrasound should prompt the arrangement of prompt outpatient follow-up (choice C) and should not be ignored (choice D). As there are multiple types of testicular neoplasms, the appearance of tumors varies. Malignant testicular tumors are usually hypoechoic but also can have hyperechoic foci. Many will have increased vascular flow on color Doppler (Figure 16.29a). Specific identification of the type of tumor may not be possible based on only ultrasound findings. The vast majority of primary testicular tumors are germ cell tumors, which are divided into seminomas and nonseminomatous germ cell tumors (Kühn et al. 2016). Besides neoplasm, the differential for a solid testicular tumor includes orchitis, testicular infarct, and abscess. Infarction can appear as a wedge shaped hypoechoic area of the testicle following epididymo-orchitis (Figure 16.29b). Testicular abscess (Figure 16.29c) can also appear similar to neoplasm but is usually associated with sonographic evidence of epididymo-orchitis. Whereas epididymo-orchitis can usually be treated with antibiotics alone (choice B), an abscess will sometimes require operative

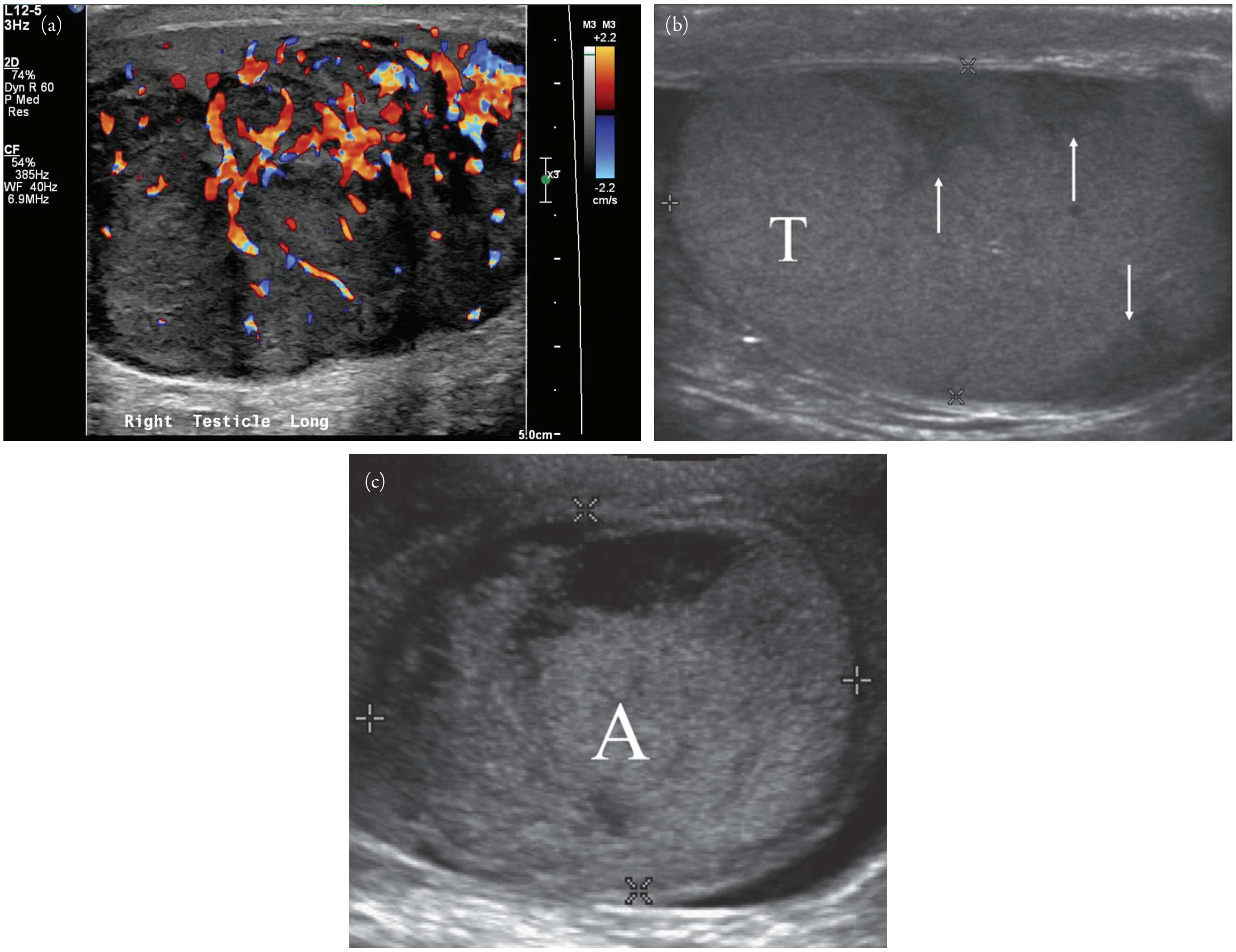

Figure 16.29 (a) **Testicular tumor with increased vascular flow.** (b) **Testicular infarct secondary to trauma.** Irregular, wedge-shaped hypoechoic areas (arrows) in a subcapsular location consistent with infarct following trauma. T = testis. Adapted from Figure 31 of Pearl MS, Hill MC. Ultrasound of the scrotum. *Semin Ultrasound CT MR*. 2007;28(4):225–248. doi:10.1053/j.sult.2007.05.001. (c) **Testicular abscess.** A = abscess. Adapted from Figure 29 of Pearl MS, Hill MC. Ultrasound of the scrotum. *Semin Ultrasound CT MR*. 2007;28(4):225–248. doi:10.1053/j.sult.2007.05.001.

drainage (choice A) (Granados et al. 1994). The appearance on ultrasound is that of a complex fluid collection, which can appear similar to a necrotic tumor.

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Pearl MS, Hill MC. Ultrasound of the scrotum. *Semin Ultrasound CT MR*. 2007;28(4):225–248.

Keywords/Tags: Testicle, malignancy, germ cell tumor, seminoma, testicular abscess, image acquisition

17.

BOWEL AND APPENDIX ULTRASOUND

Andrea Takemoto, Lindsey Ball, and J. Matthew Fields

QUESTIONS

1. You are evaluating a 7-year-old male who presents with a fever and right lower quadrant pain. Which findings on ultrasound would be the most specific for acute appendicitis?

A. Pseudokidney sign
B. Noncompressible, nonperistalsing, tubular structure measuring >6 mm in anterior-posterior diameter
C. Presence of appendicolith
D. Periappendiceal inflammation

2. A 10-year-old presents with right lower quadrant abdominal pain radiating to the right flank. You have trouble finding the appendix on ultrasound. What patient positioning can help to visualize the appendix?

A. Left lateral decubitus
B. Right lateral decubitus
C. Trendelenburg
D. Reverse Trendelenburg

3. A 16-year-old female presents with right lower quadrant pain and anorexia. You do a bedside ultrasound including measurement of the outer wall to outer wall of the appendix. Which of the following findings is *not* consistent with acute appendicitis?

A. 7 mm noncompressible, blind tubular structure with a 2 mm wall thickness
B. 8 mm noncompressible, blind tubular structure with periappendiceal fluid
C. 7 mm compressible, blind tubular structure with peristalsis
D. 6.5 mm noncompressible, blind structure with an appendicolith

4. A 35-year-old, 100 kg male presents with right lower quadrant pain and vomiting. You are unable to locate the appendix using the linear probe. What should be your next step?

A. Point-of-care ultrasound (POCUS) using a phased array probe
B. POCUS using an endocavitary probe
C. POCUS using a curvilinear probe
D. Obtain a CT of the Abdomen and Pelvis

5. While evaluating a patient for appendicitis with the ultrasound, your view is obscured by bowel gas, making it difficult to visualize any abdominal structures or landmarks. What technique will most likely improve your view?

A. Apply pressure to the probe using gentle, firm, consistent, and gradual compression.
B. Have the patient bend his or her knees.
C. Use the liver as a sonographic window.
D. Apply pressure to the probe using rapid and bouncing motions to push bowel out of the way.

6. You are evaluating a 7-year-old male with right lower quadrant pain, fever, and leukocytosis. You ultrasound his appendix and diagnose him with acute appendicitis based on the observation of each of these primary and secondary features of appendicitis *except*:

A. Periappendiceal fluid
B. Echogenic mesenteric fat
C. Mesenteric lymphadenopathy
D. Noncompressible, dilated tubular structure

7. You are beginning your ultrasound evaluation of a patient with signs and symptoms concerning for appendicitis. Common landmarks used to identify the region that is within proximity to the appendix include:

A. Psoas muscle, inferior epigastric vessels
B. Psoas muscle, iliac vessels
C. Obturator muscle, inferior epigastric vessels
D. Obturator muscle, iliac vessels

8. While performing an ultrasound evaluation for appendicitis, you approach an area in the right lower quadrant producing a dense, clean, anechoic shadow. What is the structure indicated by the calipers? (See Figure 17.1.)

Figure 17.1

A. Bowel gas
B. Appendicolith
C. Calcifications of the iliac vessels
D. Inadequate compression

9. A 7-year-old female with 24 hours of right lower quadrant pain, anorexia, and fever presents to your emergency department (ED). Though you are able to identify the appendix, you do not visualize sonographic signs of appendicitis. Given her persistent concerning symptoms, a CT scan is done an hour after the initial ultrasound, which does confirm an appendicitis at the tip of the appendix. What could have gone wrong?

A. Only the proximal portion of the appendix was visualized.
B. It was too early in the course to identify appendicitis by ultrasound.
C. Appendicitis localized to the tip cannot be identified by ultrasound.
D. The appendicitis developed between the time of the ultrasound and the CT scan.

10. You perform an ultrasound that appears to you positive for appendicitis. The surgeon on call requests a confirmatory CT scan, which shows a normal and noninflamed appendix. Which of the following is *not* a commonly reported false positive for appendicitis?

A. Periappendiceal lymph node
B. Compressed small bowel
C. Terminal ileitis
D. Right iliac pseudoaneurysm

11. A 4-week-old infant presents to the ED with 3 days of projectile vomiting. On exam, you note an olive-shaped mass in the epigastrium, which you ultrasound. (See Figure 17.2.) What criteria would help to make the diagnosis of this finding?

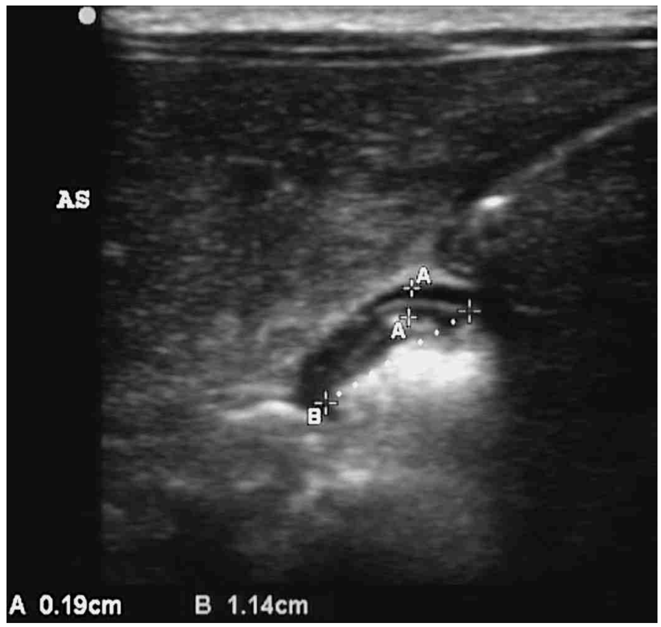

Figure 17.2 **Normal pylorus.** *Image courtesy of Geoffrey Hayden, MD.*

A. Muscle wall thickness >2 mm
B. Muscle wall thickness >3 mm
C. Length >11 mm
D. Length >12 mm

12. Which probe and orientation is optimal for visualization of the pylorus in long axis in an infant with concern for hypertrophic pyloric stenosis?

A. Curvilinear low frequency, sagittal
B. Curvilinear low frequency, transverse
C. Linear high frequency, sagittal
D. Linear high frequency, transverse

13. You are evaluating an infant for pyloric stenosis and your visualization is obscured by dirty shadowing caused by overlying bowel gas. What can you do to optimize the window?

A. Place the patient in right lateral decubitus.

B. Place the patient in left lateral decubitus.
C. Switch to a curvilinear probe.
D. Repeat the exam in 60 minutes.

14. A patient presents with nonprojectile vomiting and diarrhea. While evaluating the pylorus, you measure the muscle wall thickness of the pylorus to be >3 mm and note a double-track sign on your ultrasound. What is the most appropriate next action?

A. Confirm with an upper gastrointestinal (GI) study.
B. Consult surgery.
C. Repeat the ultrasound and observe pylorus for 5 to 10 minutes.
D. Disregard the findings because they are asymptomatic.

15. You examine a 6-week-old male with projectile vomiting. His abdomen is soft, and no mass is palpated. What is true of the following disease process?

A. Ultrasound is the preferred method for diagnosis of pyloric stenosis only when upper GI series is not available.
B. Sensitivities and specificities are comparable between ultrasound and fluoroscopy in the diagnosis of pyloric stenosis.
C. Palpation of an olive-sized mass is the most sensitive finding for diagnosis of pyloric stenosis.
D. Hypertrophied pyloric muscle can be equally visualized on ultrasound and upper GI series.

16. You examine a 2-year-old who is intermittently holding her knees to her chest. You would like to order an imaging study to evaluate her condition. Which of the following is *not* an advantage of ultrasound compared to air or contrast enema in the diagnosis of this condition?

A. Both diagnostic and therapeutic
B. Lower risk of perforation
C. Ability to identify pathologic lead point responsible
D. No exposure to radiation

17. A 1-year-old male presents with severe, intermittent abdominal pain with associated nausea and vomiting and is found to have guaiac-positive stool. You are concerned about intussusception and immediately begin to evaluate the patient with ultrasound. Where will you be most likely to locate intussusception?

A. Left upper quadrant
B. Left lower quadrant
C. Right upper quadrant
D. Right lower quadrant

18. You are evaluating a 2-year-old female who presented to the ED with severe abdominal pain and bloody stools. You perform a right upper quadrant ultrasound and find the results in Figure 17.3. You are certain that you have identified ileocecal intussusception on the ultrasound in the patient's right upper quadrant and have emergently consulted the pediatric surgeon.

What is this sign called?

A. Pseudokidney sign
B. Pseudoliver sign
C. Pseudogallbladder sign
D. Pseudostomach sign

19. You are evaluating a 50-year-old male with a history of appendectomy and hernia repair who is presenting with abdominal pain, distension, nausea, vomiting, and obstipation. To make the diagnosis of a SBO, which of the following findings is required?

A. Keyboard sign
B. Bowel wall thickness measuring >3 mm
C. Lack of peristaltic movement
D. Bowel luminal diameter measuring >25 mm

20. You are performing an ultrasound on a patient in which you suspect SBO. What finding can help differentiate a SBO from an ileus?

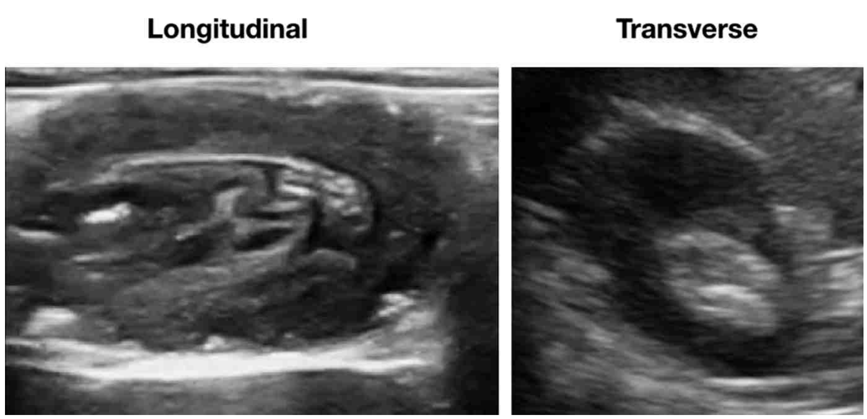

Figure 17.3

A. The presence of normal to increased peristalsis within the dilated bowel loop
B. Free fluid
C. Lack of compressibility
D. Bowel wall diameter >25 mm

21. You have diagnosed your patient with a SBO based on your ultrasound findings of noncompressible small bowel with an intraluminal diameter >25 mm with to-and-fro peristalsis. You are concerned because you have also noticed some additional abnormalities that indicate the possibility of bowel strangulation/high-grade obstruction. Which of the following findings would raise concern for bowel strangulation/high-grade obstruction?

A. Dirty shadowing
B. Localized pain with sono-palpation
C. Bowel wall thickness >3 mm
D. Intraluminal diameter >35 mm

22. You are practicing in an emergency room in Haiti and have no access to CT. In your evaluation of a 55-year-old female with left lower abdominal pain and fever, you perform an ultrasound over the area of maximum tenderness and obtain the image in Figure 17.4.

Figure 17.4 *Image courtesy of Jerry Chiricolo, MD, Department of Emergency Medicine, New York–Presbyterian Brooklyn Methodist Hospital.*

What is the most likely diagnosis?

A. Colitis
B. Perforated appendicitis
C. Acute diverticulitis
D. Sigmoid volvulus

23. You are evaluating a 75-year-old male with new onset atrial fibrillation and severe abdominal pain out of proportion to his exam. You attempt to evaluate for mesenteric ischemia with the ultrasound and note bowel wall thickening with intraperitoneal fluid. What can you do to further evaluate for mesenteric ischemia?

A. Apply color Doppler to SMA to evaluate blood flow.
B. Apply color Doppler to the segmental mesenteric arteries to evaluate blood flow.
C. Apply color Doppler to the celiac artery to evaluate blood flow.
D. Apply color Doppler to the inferior mesenteric artery to evaluate blood flow.

24. A thin 45-year-old male presents with a palpable groin protrusion that is not easily reducible. Which transducer should you most likely begin your evaluation with?

A. Curvilinear
B. Linear
C. Phased array
D. Endocavitary

25. A 45-year-old male with a history of peptic ulcer disease presents with severe and sudden onset abdominal pain, rebound, and involuntary guarding. You place transducer on his epigastrium during your initial evaluation and your view is most likely obscured by what type of artifact?

A. Reverberation artifact
B. Contact artifact
C. Mirror artifact
D. Acoustic enhancement

ANSWERS

1. EXPLANATION

B. Noncompressible, nonperistalsing, tubular structure measuring >6 mm in anterior-posterior. While there are many signs suggestive of appendicitis on ultrasound that can be helpful for diagnosis, the most specific finding is a noncompressible, nonperistalsing, tubular structure measuring >6 mm in anterior-posterior diameter (see Video 17.1, Figure 17.5a, Figure 17.5b). Other findings include target shape or "bull's eye" appearance in transverse view and periappendiceal inflammation that can be visualized as increased echogenicity in the surrounding fat around the appendix, free fluid, or abscess. Presence of an appendicolith can be helpful in diagnosing acute appendicitis, but this can also be present without appendicitis and should not be used alone to confirm a diagnosis.

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Keywords/Tags: Appendicitis, pediatrics

Learning Point 1: The classic findings of appendicitis include the following: target shape or bull's eye appearance in transverse view, outer diameter >6 mm, noncompressible blind-ended tubular structure, presence of appendicolith, lack of peristalsis, and periappendiceal fluid.

2. EXPLANATION

A. Left lateral decubitus. The appendix lies in the retrocecal position in over 25% of patients (Figure 17.6a). Placing the patient in the left lateral decubitus position, also known as the left posterior oblique position, can improve success rates of visualization of the retrocecal appendix when the view is not obtainable in the supine position. In the left lateral decubitus position, the appendix is found by scanning coronally through the right flank, parallel to the psoas muscle (Figure 17.6b). Additionally, this repositioning may also provide the benefit of shifting bowel contents to improve overall acoustic window. Alternatively, the appendix may be found by scanning in the longitudinal plane beginning at the anterior axillary line and continuing around the flank to the posterior axillary line (Figure 17.7a). Another technique involves a suprapubic approach, using a full urinary

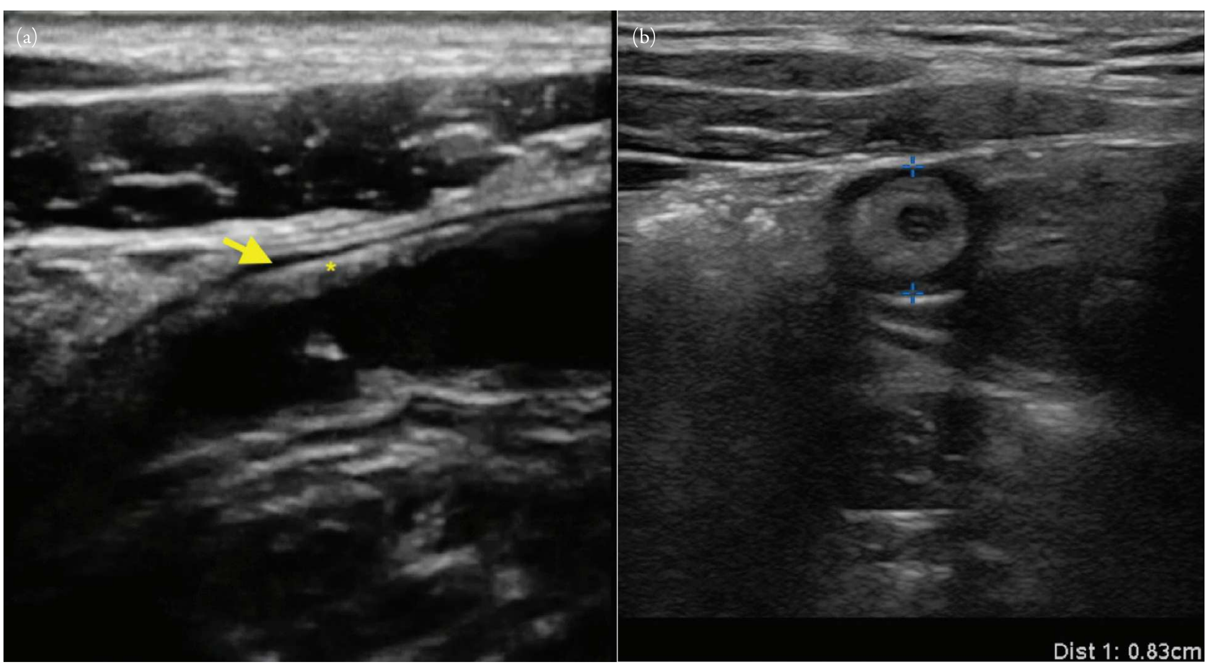
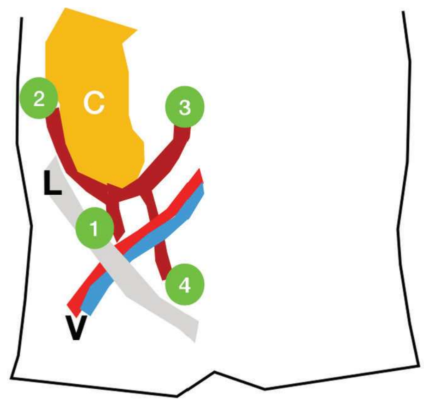


Figure 17.5 (a) **Ultrasound findings of acute appendicitis.** This longitudinal image of acute appendicitis demonstrates a diameter >6 mm, thickening of the bowel wall (*), and periappendiceal fluid (arrow). (b) **Ultrasound findings of acute appendicitis.** This transverse image of acute appendicitis demonstrates a diameter >6 mm with a target sign.

bladder as an acoustic window to visualize the appendix just posterior to or lateral to the bladder (Figure 17.7b).

(a)



(b)

Figure 17.6 (a) **Possible positions of the appendix on ultrasound.** Normally the appendix (1) is inferior to the cecum (C), medial to the inguinal ligament (L), and lateral to the iliac vessels (V). However, appendicitis can localize to the right upper quadrant or flank if the appendix is retrocecal (2). It can also localize to the medial abdomen in abdominal appendicitis (3), or in the suprapubic region in deep pelvic appendicitis (4). (b) **Scanning in the left lateral decubitus position.** Image demonstrating scanning technique parallel to psoas muscle with patient in left lateral decubitus position.

(a) (b)

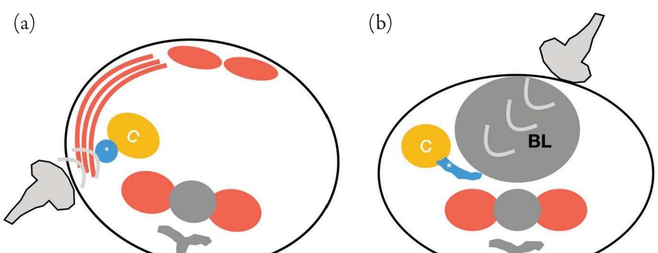


Figure 17.7 **Alternative techniques to identify a retrocecal or deep pelvic appendix.** (a) scanning through the right flank to identify a retrocecal appendix (*). The cecum (C) is visualized deep to the appendix when using this approach. (b) using a full urinary bladder as an acoustic window to identify a deep pelvic appendix (*) through the posterior lateral wall of the bladder (BL).

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Keywords/Tags: Retrocecal appendix, positioning

Learning Point 2: It might be helpful to place a patient in the left lateral decubitus position to increase the chance of visualizing a retrocecal appendix.

3. EXPLANATION

C. 7 mm compressible, blind tubular structure with peristalsis. The diameter of a normal appendix may sometimes overlap with what is considered abnormal (>6 mm) and is not sufficient for diagnosis without additional findings. Because of this overlap, a diameter measuring ≤ 6 mm is useful in ruling out appendicitis. However, in isolation, a diameter >6 mm does not rule in appendicitis, and several studies have suggested better specificity using a maximum outer diameter of >7 mm.

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Keywords/Tags: Appendix, measurements

Learning Point 3: Appendicitis can be excluded when the anterior-posterior diameter of the appendix from outer wall to outer wall is measured to be ≤ 6 mm, but it is important to note a normal appendix can sometimes exceed this diameter.

4. EXPLANATION

C. POCUS using a curvilinear probe. While the high-frequency linear transducer is ideal for evaluation of

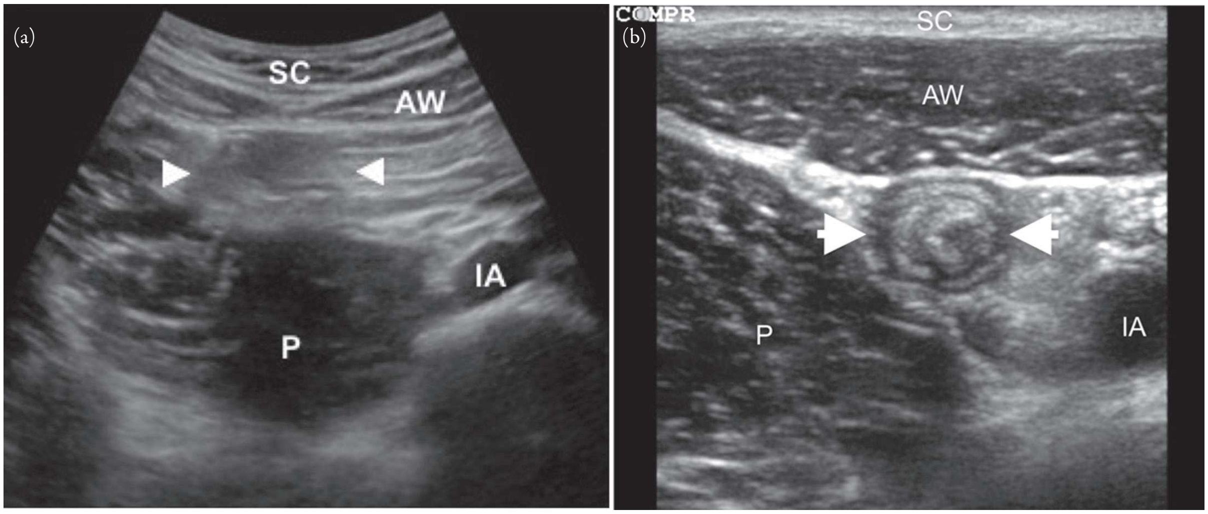

Figure 17.8 ***Comparison view of two normal appendices.*** (a) using the curvilinear transducer on a patient with normal body habitus and (b) using the linear transducer on a thin patient. Note the relative depth of various structures including the subcutaneous tissue (SC), abdominal wall (AW), appendix (bounded by white arrows), psoas muscle (P), iliac artery (IA).

appendicitis in the pediatric or adult patient with a small body habitus, both adult and pediatric patients with a larger body habitus present a challenge to sonographic diagnosis of appendicitis. Adipose tissue attenuates sound waves, making the ultrasound image difficult and sometimes impossible to interpret. This patient population will usually require the lower frequency curvilinear probe to improve adipose tissue penetration.

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Keywords/Tags: Probe selection, appendicitis

Learning Point 4: In patients with a higher body mass index (≥25 in adults and ≥85th percentile for age in children), the sensitivity of ultrasound for the diagnosis of acute appendicitis decreases and the incidence of a nondiagnostic study increases. Using a curvilinear rather than linear transducer may enable better tissue penetration and image acquisition and mitigate the need for reexamination with computed tomography (CT), which has excellent sensitivity and specificity even in overweight and obese patients.

5. EXPLANATION

A. Apply pressure to the probe using gentle, firm, consistent, and gradual compression. Considered standard technique in the evaluation of appendicitis, graded compression consists of a gentle, firm, consistent, and gradual compression with the transducer that improves visualization of abdominal landmarks by displacing intraluminal gas and mobile bowel while simultaneously isolating abnormal bowel loops. This technique improves the image by eliminating artifact. With adequate graded compression, the iliac vessels and psoas muscle should be visualized as standard anatomical landmarks (Figure 17.9, Video 17.2). While the patient bending his or her knees may make the abdominal wall softer and the patient more comfortable, it does not displace bowel gas. The use of the liver as a sonographic window is helpful in visualizing structures in the thorax. However, it does not help to visualize the appendix, which is in a different abdominal quadrant. Rapid,

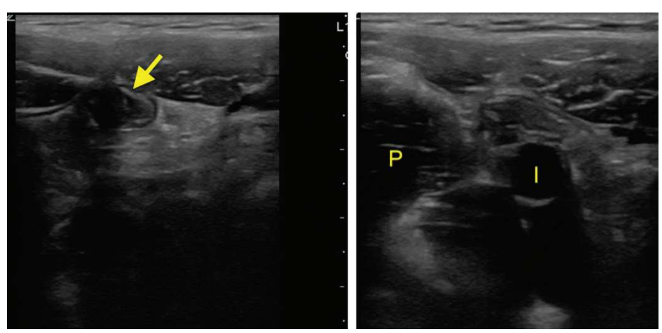

Figure 17.9 **Normal appendix without (left) and with compression (right) on ultrasound.** Note that the appendix diameter is <5 mm with compression, as well as the presence of the psoas muscle (P) and the iliac artery (I), which appear into view with compression.

bouncing application of pressure to the abdomen is uncomfortable and will not displace bowel gas.

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Keywords/Tags: Graded compression, technique, appendix

Learning Point 5: To displace intraluminal gas and mobile bowel while simultaneously isolating abnormal bowel loops, use the technique of graded compression, which consists of firm, constant pressure to gradually compress the abdominal wall.

6. EXPLANATION

C. Mesenteric lymphadenopathy. While this finding is nonspecific, in the setting of right lower quadrant pain in a pediatric patient, isolated lymphadenopathy would be more suggestive of mesenteric adenitis than appendicitis (Figure 17.10a). Generally accepted secondary signs of appendicitis on ultrasound include periappendiceal fluid and echogenic mesenteric fat (the equivalent to fat standing on CT, as shown in Figure 17.10b, Video 17.3), pelvic free fluid/fluid collection, or abscess formation. When the appendix is not visualized, these secondary findings of appendicitis can aid in the diagnosis.

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Keywords/Tags: Appendicitis, secondary signs

Learning Point 6: When not able to visualize the appendix on ultrasound, identifying secondary findings of acute appendicitis may aid in the diagnosis.

7. EXPLANATION

B. Psoas muscle, iliac vessels. The appendix can lie in a variety of positions within the abdominal cavity. Because of this variability, there is no single transducer position that can reliably provide consistent visualization. While there is variability in the initial approach to locating the appendix with ultrasound, the appendix is commonly found between the abdominal musculature and the psoas muscle, in proximity to the iliac vessels, with these landmarks assisting in the identification the appropriate region (see Figure 17.8).

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Keywords/Tags: Appendicitis, landmarks

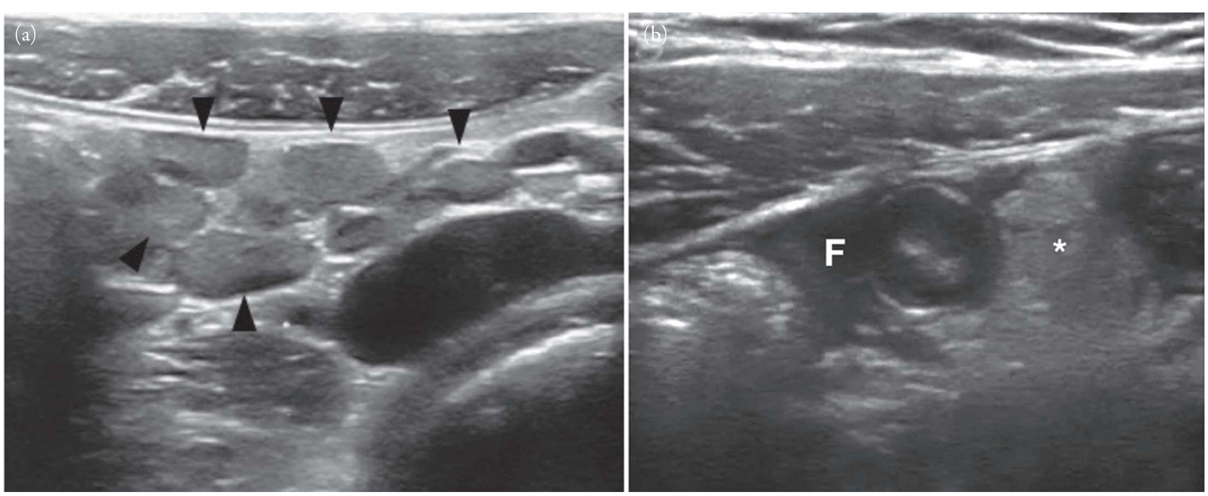

Figure 17.10 (a) **Mesenteric adenopathy.** Image showing mesenteric lymphadenopathy, which is not a secondary finding of appendicitis. This finding is more consistent with the diagnosis of mesenteric adenitis. (b) **Appendicitis** with periappendiceal fluid (F) and echogenic fat (*).

Learning Point 7: While there is variability in the initial approach to locating the appendix with ultrasound, the appendix is commonly found between the abdominal musculature and the psoas muscle, in proximity to the iliac vessels, with these landmarks assisting in the identification.

8. EXPLANATION

B. Appendicolith. When seen in combination with an enlarged and inflamed appendicitis, an appendicolith can aid in the diagnosis of appendicitis. Figure 17.1 shows an appendicolith as well as periappendiceal fat in this patient with acute appendicitis. However, an appendicolith in isolation is not diagnostic of appendicitis. The bright, echogenic appearance of an appendicolith produces a dense and anechoic shadow similarly to gallstones or renal calculi, in contrast to the "dirty" mixed echogenicity shadowing produced by air within the lumen. Additionally, the echogenic appearance of an appendicolith differs from that of a calcified vessel, as the posterior wall will not be seen due to shadowing, while in vascular calcifications there will an echogenic rim along with edge artifact when imaged in the transverse axis (Figure 17.11).

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Keywords/Tags: Appendicolith, shadowing, appendicitis

Learning Point 8: The bright, echogenic appearance of an appendicolith produces a dense and anechoic shadow similarly to gallstones or renal calculi, in contrast to the "dirty" mixed echogenicity shadowing produced by air within the lumen.

9. EXPLANATION

A. Only the proximal portion of the appendix was visualized. In addition to visualizing the proximal portions of the appendix, the tip of the appendix must also be visualized. It is possible to visualize the tip of the appendix on ultrasound (Figure 17.12). Failing to evaluate the distal tip of the appendix can lead to missing cases that only have isolated distal inflammation. For this reason, it is essential to visualize the entire appendix on ultrasound, which can be further complicated by the variability in appendix position within the abdomen.

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Keywords/Tags: Appendicitis, pitfalls

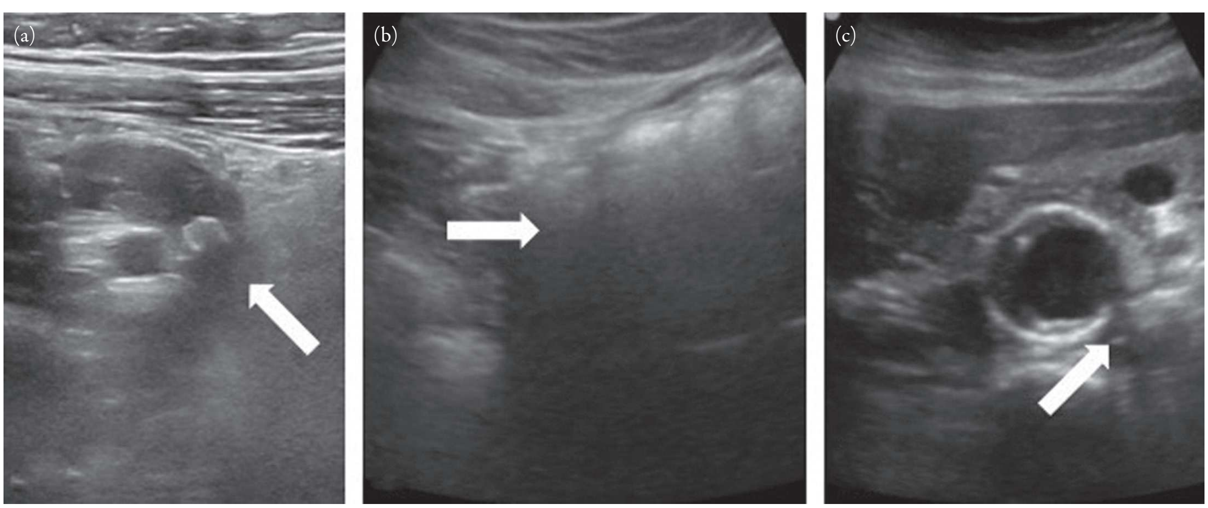

Figure 17.11 **Different types of shadowing.** Image showing shadowing (white arrows) secondary to (a) appendicolith, (b) bowel wall, and (c) vascular calcification.

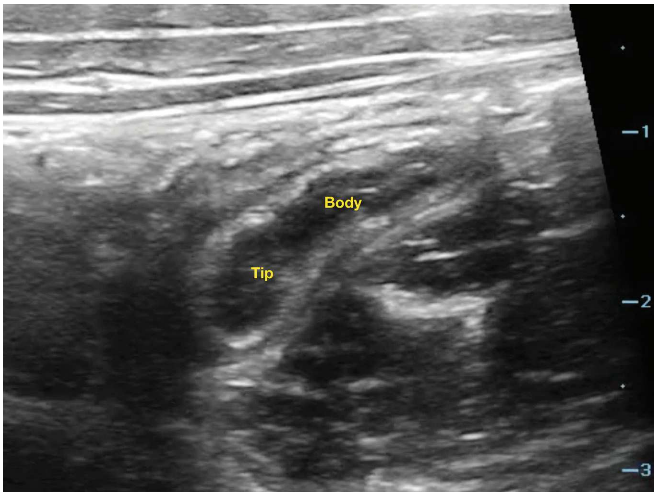

Figure 17.12 **Appendicitis with prominent tip involvement.**

Learning Point 9: Appendicitis can be missed with inadequate visualization of the distal portion of the appendix to evaluate inflammation at the tip. If appendix ultrasound is negative but there is still suspicion, it may be prudent to continue evaluation with serial exams or with CT.

10. EXPLANATION

D. Right iliac pseudoaneurysm. Visualization of the appendix in both the transverse and longitudinal planes reduces the risk of misidentifying another structure as the appendix. The most common misidentification scenario is mistaking a regional lymph node (Figure 17.10a) or compressed small bowel for the appendix. Terminal ileitis and ureteritis can also easily be confused for appendicitis if the structure is not confirmed to have a blind end using two planes for visualization (see Figure 17.13). While bowel gas and artifact may obscure visualization of the appendix, it is more likely they would lead to a suboptimal and incomplete exam than a misidentification of the appendix. While right iliac pseudoaneurysm is a rare presentation that can mimic appendicitis clinically on history and physical, this is not commonly misidentified on ultrasound given its distinct vascular features that vary from the appendix. Though sensitivity and specificity of ultrasound for the diagnosis of appendicitis is improving and some studies show sensitivities and specificities to be similar to CT, CT continues to have overall greater accuracy and reliability over sonography.

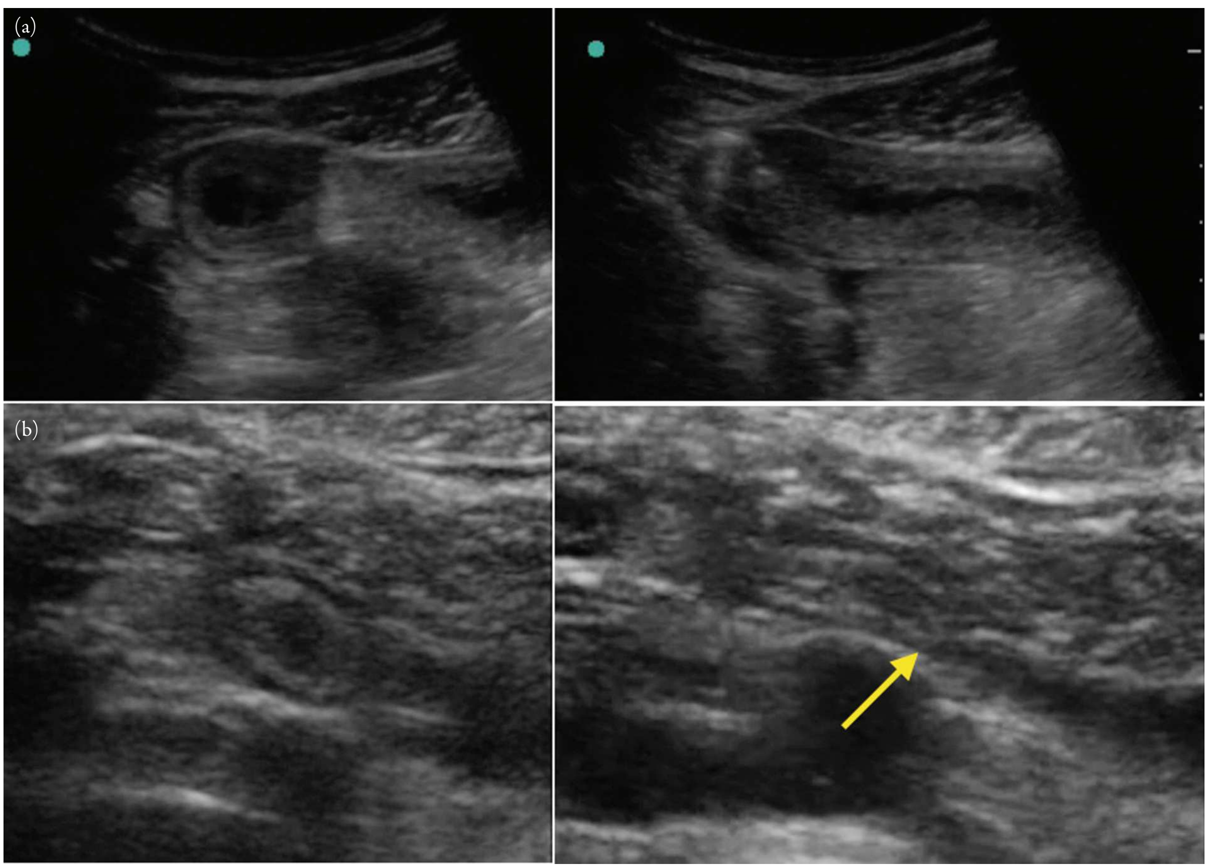

Figure 17.13 (a) **Ileitis as a mimic for appendicitis.** Visualization of the tubular structure in both short axis (left panel) and long axis (right) can help to identify this structure as ileum and not appendix. (b) **Ureteritis mimicking acute appendicitis in a cross-sectional image.** Upon rotating the transducer from short to long axis, the structure is noted to not end in a blind loop (arrow).

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Keywords/Tags: Appendicitis, pitfalls

Learning Point 10: The appendix must always be visualized in both planes to avoid misidentifying lymph nodes or small bowel for the appendix.

11. EXPLANATION

B. Muscle wall thickness >3 mm. The pylorus is a ring of muscle separating the pyloric antrum from the duodenum. A normal pylorus has a muscle wall thickness of ≤ 3 mm and a length of ≤ 14 mm (Figure 17.2). A muscle wall thickness >3 mm that does not vary with time is widely accepted as diagnostic of pyloric stenosis. In pyloric stenosis, the pyloric muscle hypertrophies, causing an increase in the length and thickness from the nonpathologic pylorus (Figure 7.14a).

Care should be taken to ensure the measurement is made at a perpendicular cross section in the midline of the longitudinal axis to obtain an accurate measurement, as being off even 1 to 2 mm can affect the diagnosis. Additionally, it is key to only measure the hypoechoic muscle layer and not the more echogenic mucosa to avoid overestimating the measurement (Figure 17.14b). The longitudinal muscle wall length is considered the most accurate and widely accepted diagnostic criterion.

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Keywords/Tags: Pyloric stenosis, measurements

Learning Point 11: In pyloric stenosis, the pylorus muscle hypertrophies, causing an increase in the length and thickness from the nonpathologic pylorus, which normally has a muscle wall thickness of ≤ 3 mm and a length of ≤ 14 mm.

12. EXPLANATION

D. Linear high frequency, transverse. Evaluation of pyloric stenosis should be performed from an anterior approach with the patient in the supine position with a linear, high-frequency transducer in the transverse plane. In general, pediatric applications are best done with the high-frequency linear probe because most important structures are found at a relatively shallow depth. The anterior gastric

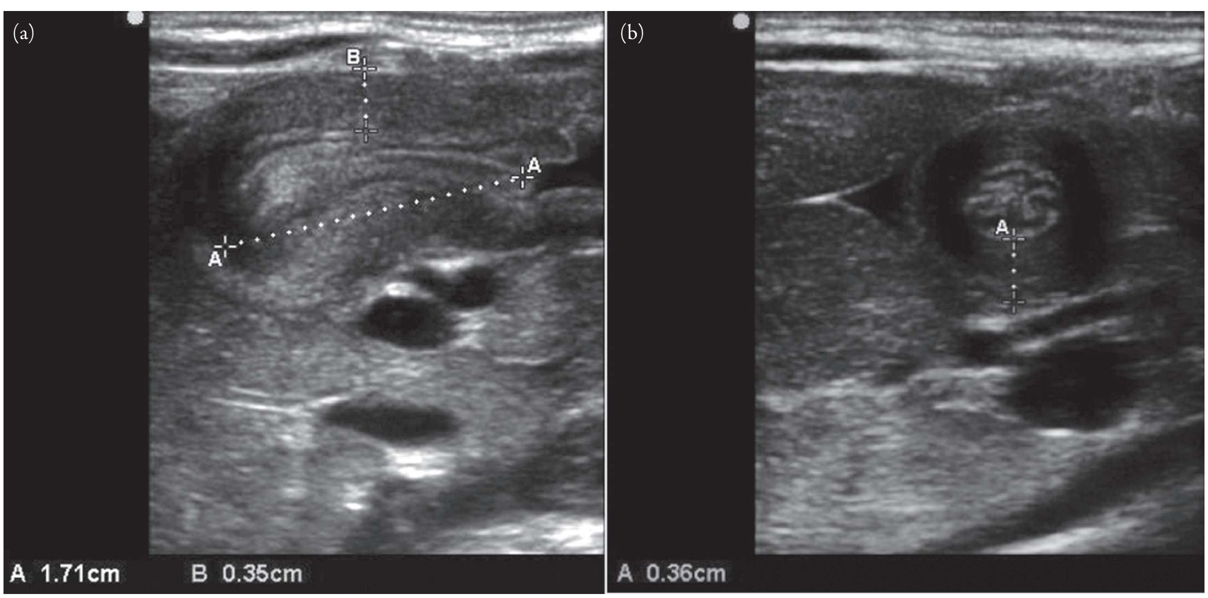

Figure 17.14 (a) **Hypertrophic pylorus.** *Image courtesy of Geoffrey Hayden, MD.* (b) **Hypertrophic pyloric stenosis in transverse plane.** *Image courtesy of Geoffrey Hayden, MD.*

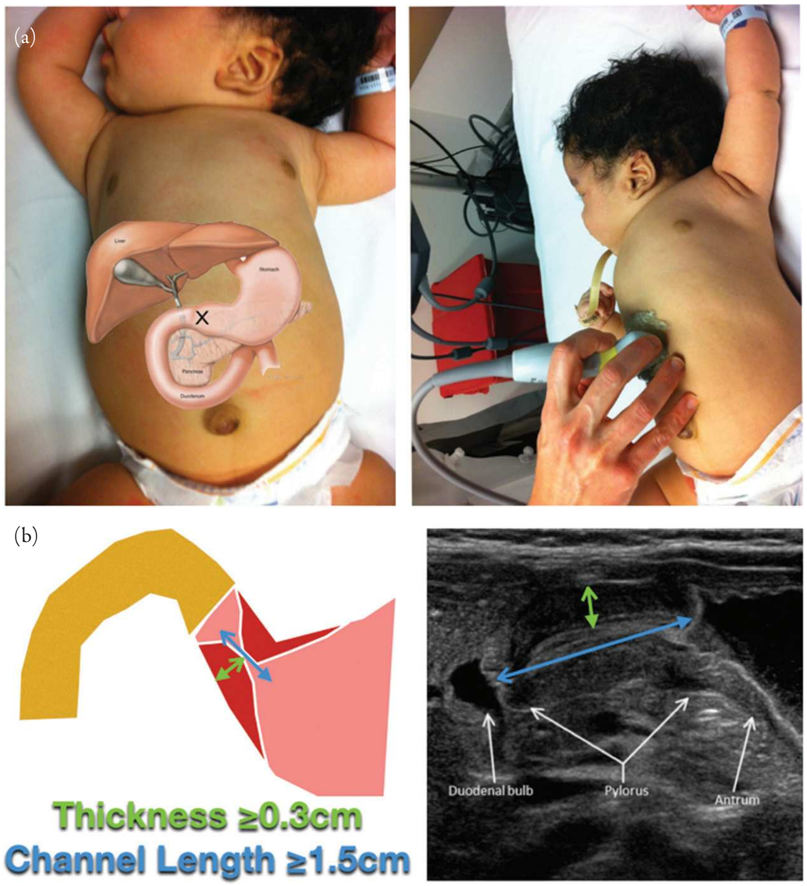

Figure 17.15 (a) **Patient positioning for pylorus assessment.** *Image courtesy of Jennifer R. Marin, MD MSc.* (b) **Measurement of the pylorus.** *Image courtesy of Jennifer R. Marin, MD MSc.*

wall can be traced laterally by starting in the subxiphoid position, using the liver as an acoustic window. Contiguous with the stomach, the pylorus is usually slightly right of the midline and caudal to the gallbladder. The pylorus will be located between the pyloric antrum and the duodenum. The beginning of the pyloric antrum can be identified with its notched appearance in the gastric wall, known as incisura angularis. Here, even the nonpathologic pyloric muscle will be identified in the long axis with its slightly thickened appearance. The end of the pyloric channel where it meets the duodenum is identified by the curved appearance and abrupt change in thickness of the muscle wall, though the length and shape of the channel is dynamic and can vary with stages of peristalsis (Figure 17.15a).

Measurement should be of the thickness of the pylorus muscle, as well as the channel length. Normal values should be ≤ 3 mm and ≤ 14 mm, respectively (Figure 17.15b).

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Keywords/Tags: Pyloric stenosis, technique

Learning Point 12: Evaluation of pyloric stenosis should be performed with the patient in the supine position with a linear, high-frequency probe.

13. EXPLANATION

A. Place the patient in the right lateral decubitus. Placing the patient in the right lateral decubitus assists in filling the pyloric antrum with gastric fluid, creating a better and more echogenic window by moving gastric air toward the fundus and out of view (Figure 17.16). Additionally, if the infant's stomach is empty, it can be helpful to have the patient drink a small amount prior to the exam to obtain this optimized window. The left lateral decubitus position would be useful in the scenario where there is gastric fluid

over distention and a pylorus that is displaced more posteriorly. This maneuver can elevate the pylorus, moving it more anteriorly and closer to the transducer. While it can be helpful for penetration of soft tissue and adipose tissue, a curvilinear probe would not decrease bowel gas artifact. Repeating the exam in 60 minutes would not lead to any predictable improvement in the window.

Figure 17.16 **Infant in right lateral decubitus position.** *Image courtesy of Jennifer R. Marin, MD MSc.*

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Keywords/Tags: Pyloric stenosis, positioning

Learning Point 13: Positioning the infant in the right lateral decubitus position can help create a better window for visualization of the pylorus by moving the gastric fluid to fill the pyloric antrum and allowing view-obscuring gastric air to move toward the fundus.

14. EXPLANATION

C. Repeat the ultrasound and observe pylorus for 5 to 10 minutes. Pylorospasm, a normal occurrence that causes the pyloric channel to transiently collapse for up to 5 to 10 minutes, can increase the pyloric muscle wall thickness measurement to >3 mm. Because of the dynamic function of the musculature, it should generally be evaluated for a 5- to 10-minute period, and repeat measurements should be obtained over this time to differentiate pylorospasm from pyloric stenosis (Figure 17.17). The increased muscle wall thickness is a normal variant and should occur only transiently. Over time the muscle wall should once again relax and gastric contents should once again be able to pass. If suspicion for pyloric stenosis is high and the initial ultrasound

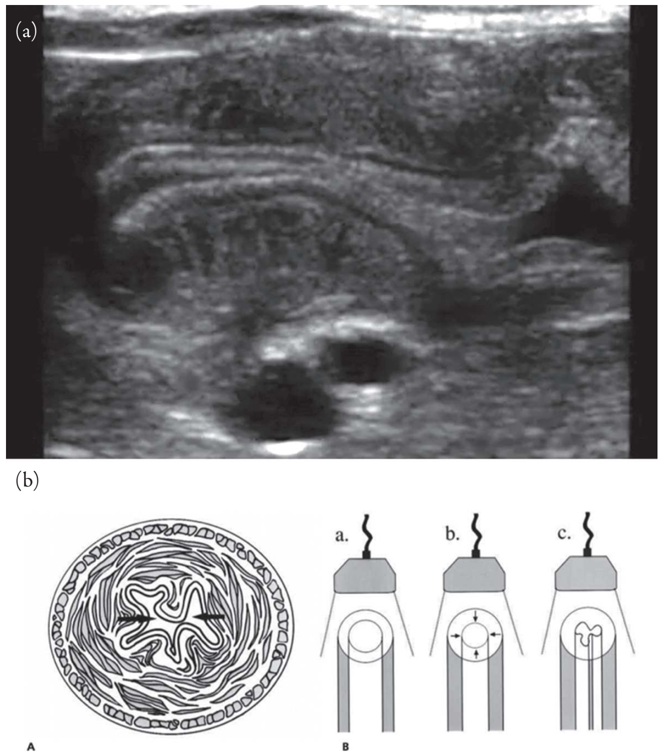

Figure 17.17 (a) **Double-track sign.** Longitudinal sonogram of the pylorus showing a double-track sign, which is not specific for hypertrophic pyloric stenosis and can also be seen in pylorospasm. *Image courtesy of Geoffrey Hayden, MD.* (b) **The double-track sign: diagrammatic representation.** (a) Cross section through the pyloric area. Two arrows point to portions of the lumen of the pyloric channel, which is usually a single tube but in this case is irregularly shaped because of its impingement by the mass of the thick surrounding pyloric muscle on the pyloric channel. Fluid in each portion of the lumen may be seen as a separate echoless track. (b) Theoretical cause of the sonographic double-track sign. (a) Linear array transducer overlying a cross section of the pylorus. Deep to the pylorus in the diagram is the theoretical sonographic image. The pyloric muscle wall is seen as gray or echogenic. The area of the fluid-filled pylorus is seen as white or echoless/echopenic. (b) Similar to (a) but with the addition of arrows in the pyloric wall suggesting mass impression on the pyloric channel. (c) Example of how the mass impression on the channel has caused the channel to be irregular in shape with a portion of the image beyond the fluid-filled channel white or echoless, consistent with fluid, and between it an area that appears gray or echogenic, consistent with a lack of fluid in the area. The echogenic area helps visually separate the echoless canal into 2 echoless channels. From Figure 4 of Cohen HL, Blumer SL, Zucconi WB. The sonographic double-track sign: not pathognomonic for hypertrophic pyloric stenosis can be seen in pylorospasm. *J Ultrasound Med.* 2004;23(5):641–646.

is nondiagnostic or negative despite a patient's persistent signs and symptoms, it may be appropriate to either repeat the ultrasound or follow it with an upper GI study.

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Keywords/Tags: Pyloric stenosis

Learning Point 14: Pylorospasm, a normal occurrence that causes the pyloric channel to transiently collapse for up to 5 to 10 minutes, can increase the pyloric muscle wall thickness measurement to >3 mm. If this is suspected, repeat measurements should be obtained over time to differentiate pylorospasm from pyloric stenosis.

15. EXPLANATION

B. Sensitivities and specificities are comparable between ultrasound and fluoroscopy in the diagnosis of pyloric stenosis. A palpable olive-sized mass in the epigastrium along with a history of projectile vomiting is the classic presentation for pyloric stenosis. However, it is rare to have this combination, and imaging is needed to confirm the diagnosis. Despite comparable accuracy approaching 100% of both ultrasound and fluoroscopy in the diagnosis of pyloric stenosis, ultrasound is the standard for diagnosis because of its rapid and noninvasive assessment of the pylorus with the added benefit of no exposure to ionizing radiation. An upper GI series does not directly visualize the hypertrophied pylorus and instead implies it through visualization of thinned channels of barium through the pylorus (Figure 17.18). This contrasts with sonography, where hypertrophied muscle is directly visualized. An upper GI series is not required to confirm a positive diagnosis but may be considered if there is still clinical suspicion after a non-diagnostic ultrasound.

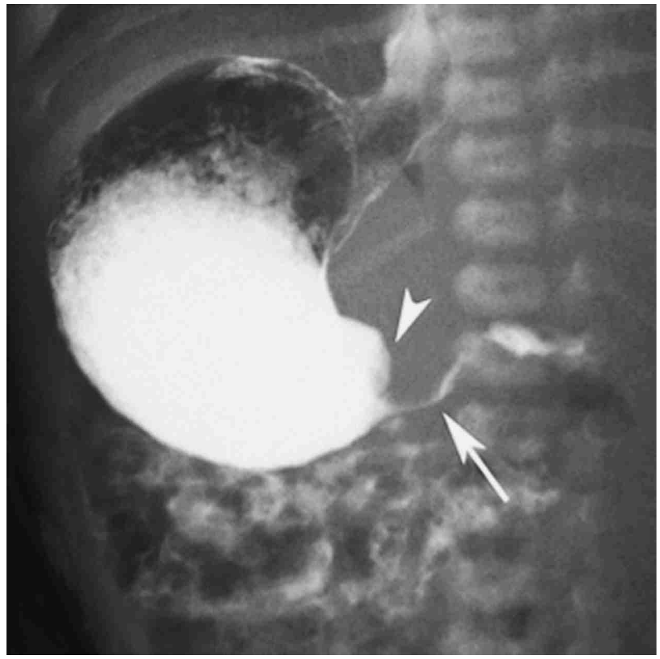

Figure 17.18 **Upper GI series demonstrating the string sign in pyloric stenosis.** From Figure 35.4 of Paladin, AM. Hypertrophic pyloric stenosis. In: Reid J, Lee E, Paladin A, Carrico C, and Davros W, eds. *Pediatric Radiology*. New York, NY: Oxford University Press, 2014.

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Keywords/Tags: Pyloric stenosis

Learning Point 15: Ultrasound is the primary modality for the diagnosis of pyloric stenosis, with sensitivities and specificities comparable to fluoroscopy with the benefit of no exposure to ionizing radiation.

16. EXPLANATION

A. Both diagnostic and therapeutic. Ultrasound has many advantages over enema for the diagnosis of intussusception. These include lower risk of perforation, the ability to identify the pathologic lead point causing the intussusception, noninvasive method, and reduced exposure to radiation. The classic finding is a target sign (Figure 17.19). Both studies also have similar accuracies, with ultrasound being 98.5% to 100% sensitive and 88% to 100% specific with a 100% negative predictive value.

However, the main disadvantage to ultrasound in this diagnosis is that the patient will ultimately still need a contrast enema for the treatment itself. This makes the topic

Figure 17.19 ***Target sign.*** Image depicting a target sign, the classic sonographic finding of intussusception in which the intussusceptum telescopes within a loop of bowel.

somewhat controversial in deciding which study to choose first. Traditionally, contrast enema has been considered the gold standard due to its diagnostic and therapeutic properties, but ultrasound has recently gained more favor because of the reasons discussed. Additionally, rates of successful hydrostatic reduction under ultrasound guidance have been reported at >90% and are comparable to barium enema under fluoroscopy. Hydrostatic reduction typically is performed under sedation with a urinary catheter bulb inserted into the rectum and inflated distal to the affected bowel to form a seal. Saline or a near-physiologic solution is slowly infused via the catheter, while the ultrasound transducer is placed at the intussuscepted bowel. Steady infusion of fluid will gradually fill the affected bowel and reduce it due to the hydrostatic effect of the fluid.

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Keywords/Tags: Intussusception

Learning Point 16: There are distinct advantages of ultrasound over contrast enema in the diagnosis of intussusception.

17. EXPLANATION

C. Right upper quadrant. Ileocolic intussusception is the most common intussusception found in the classic age range of 6 months to 2 years and is most commonly identified in the right upper quadrant. A high-frequency linear probe should be used with the patient in the supine position to allow for evaluation of the entire colon. The exam should begin in the transverse plane at the hepatic flexure, identifying the transverse and ascending colon and tracing down the lateral abdomen toward the cecum to the ileocecal junction. Visualizing peristalsis of the terminal ileum leading to a normal cecum can rule out ileocolic intussusception. If an abdominal mass is palpated, this area should then be imaged in multiple planes. If no mass found, you can continue the exam from the cecum/distal ileum up to the transverse colon and down to the left lower quadrant to as distally as possible, searching for a mass that would be deep to the abdominal wall.

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Keywords/Tags: intussusception

Learning Point 17: Ileocolic intussusception is the most common intussusception and is most often found in the right upper quadrant after beginning exam in the transverse plane at the hepatic flexure, identifying the transverse and ascending colon and tracing down toward the cecum to the ileocecal junction.

18. EXPLANATION

A. Pseudokidney sign. Ileocolic intussusception, in the longitudinal plane, can appear as a multilaminar structure often described as appearing similar a kidney, "pseudokidney sign," which occurs when multiple thick hypoechoic layers appear distinctly different from normal proximal and distal bowel. In the transverse plane, it more classically presents with the "target sign" or "multiple concentric ring sign," which consists of a hyperechoic center of bowel contents surrounded by a hypoechoic ring of bowel wall, typically measuring 3 to 5 cm in diameter. In contrast, normal bowel will appear as hypoechoic bowel contents surrounded by a hyperechoic ring. While the pseudokidney sign is highly sensitive and specific for intussusception, false-positives

have been reported including feces in the colon, perforated Meckel diverticulum with malrotation and Ladd bands, psoas muscle, and hematoma.

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Keywords/Tags: Intussusception

Learning Point 18: Ileocolic intussusception imaged in the transverse plane classically presents with the “target sign” or “multiple concentric ring sign,” which consists of a hyperechoic center of bowel contents surrounded by a hypoechoic ring of bowel wall, typically measuring 3 to 5 cm in diameter. In the longitudinal plane, intussusception can appear as a multilaminar structure often described as appearing similar a kidney, the “pseudokidney sign,” which occurs when multiple thick hypoechoic layers appear distinctly different from normal proximal and distal bowel.

19. EXPLANATION

D. Bowel luminal diameter measuring >25 mm. Dilated, fluid-filled, noncompressible small bowel loops with peristaltic to-and-fro movements and luminal diameter measuring >25 mm in maximum diameter are all findings suggestive of a SBO. Using the primary diagnostic criterion of loops of bowel dilated >25 mm, ultrasound has excellent sensitivity and specificity for the diagnosis of SBO—92% and 97%, respectively, in one meta-analysis. The classic “keyboard sign,” visualizing Kerckring’s folds (also known as plicae circulares or valvulae conniventes), is also often found in SBO (Figure 17.20a). However, its presence is not essential for diagnosis, and it is rarely seen in the terminal ileum. Small bowel normally has a luminal diameter <25 mm and is easily compressible with gentle pressure. Bowel wall thickening to >3 mm does not always occur in a bowel obstruction, but its occurrence is suggestive of a high-grade obstruction (Figure 17.20b, Video 17.5).

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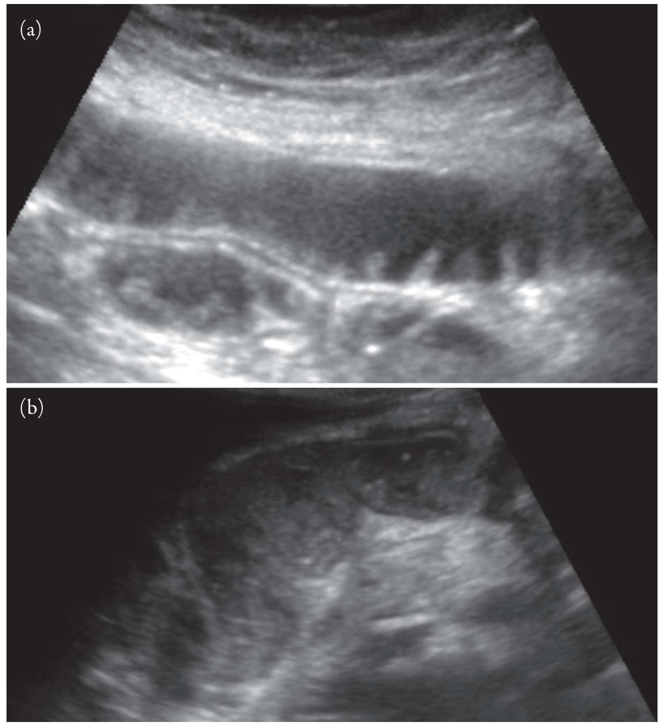

Figure 17.20 (a) **Keyboard sign.** Image visualizing Kerckring’s folds in the classic “keyboard sign” of small bowel obstruction. (b) **Small bowel obstruction.** Fluid-filled and dilated loops of bowel >25 mm, consistent with small bowel obstruction

Ogata M, Imai S, Hosotani R, et al. Abdominal sonography for the diagnosis of strangulation in small bowel obstruction. *Br J Surg*. 1994;81:421–424.

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Keywords/Tags: Small bowel obstruction, diagnostic criteria

Learning Point 19: Dilated, fluid-filled, noncompressible small bowel loops with peristaltic to-and-fro movements and luminal diameter measuring >25 mm in maximum diameter are findings suggestive of a small bowel obstruction (SBO).

20. EXPLANATION

A. The presence of normal to increased peristalsis. Differentiating SBO from ileus can be difficult as each may cause dilated loops of bowel. A way to distinguish the diagnoses is the presence and degree of peristalsis, which should be normal or increased in SBO and diminished or absent in ileus. Detecting a transition point in a SBO may be useful in the diagnosis of SBO but is often challenging to visualize, and its absence does not rule out SBO. A transition point

may be found by following abnormal dilated bowel until normal, collapsed bowel is visualized adjacently. A transition point will show a distinct point of transition between dilated proximal bowel and distal collapsed bowel. SBO and ileus share many similarities on ultrasound, including bowel dilatation with luminal diameter generally exceeding 25 mm. Though lack of compressibility of the bowel makes an ileus less likely, it is not a reliable finding to differentiate SBO and ileus. Free fluid is a nonspecific finding that can be found in a high-grade SBO but is generally not correlated with an ileus. Ileus commonly will have gas echoes, which tend to be more dominant than intraluminal fluid.

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Keywords/Tags: Small bowel obstruction

Learning Point 20: The presence of peristalsis within a fluid-filled dilated loop of bowel can be useful when trying to differentiate SBO from an ileus. A transition point for SBO is very difficult to find on ultrasound.

21. EXPLANATION

C. Bowel wall thickness >3 mm. Signs indicating a high-grade obstruction/bowel strangulation include edematous bowel wall measuring >3 mm, localized intraperitoneal free fluid surrounding noncompressible, dilated bowel. Early bowel strangulation criteria include an akinetic dilated loop, presence of peristaltic activity in dilated small bowel proximal to the akinetic loop, and rapid accumulation of intraperitoneal fluid. A later finding in bowel strangulation is identified by an asymmetric wall thickening >3 mm with an increased echogenicity in the akinetic loop, or a significant amount of peritoneal fluid containing scattered spot echoes that indicate bloody ascites. Vascular flow within the bowel wall may be useful in identifying segments at risk of strangulation. Hollerweger (2016) also describes identification of hyperechoic thickening of the mesentery of strangulated bowel. Dirty shadowing would be associated with bowel gas and not with bowel strangulation. Localized pain to sono-palpation is a nonspecific finding and could occur with most pathologic intraabdominal processes. A small bowel intraluminal diameter >35 mm exceeds criteria for diagnosis of a SBO but does not necessarily indicate strangulation.

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Keywords/Tags: Small bowel obstruction

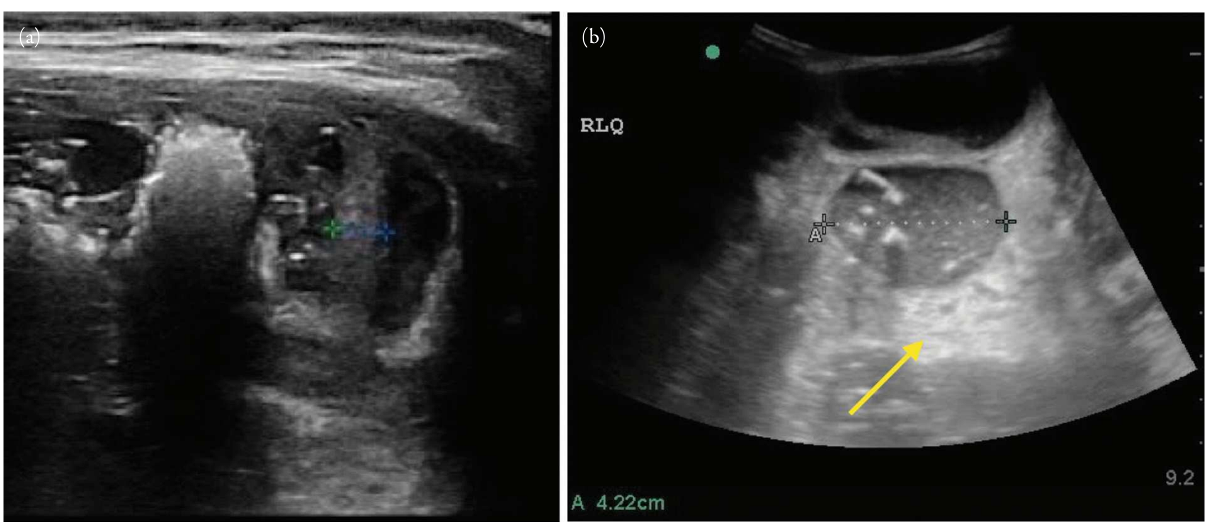

Figure 17.21 **Secondary findings in high grade obstruction/strangulation.** Images showing (a) bowel wall thickening >3 mm and (b) strangulated bowel with hyperechoic thickening of its mesentery (arrow).

Learning Point 21: Secondary signs indicating a high-grade obstruction/bowel strangulation include edematous bowel wall measuring >3 mm and localized intraperitoneal free fluid surrounding noncompressible, dilated bowel.

22. EXPLANATION

C. Acute diverticulitis. Acute diverticulitis has a distinct appearance on ultrasound that can be identified as an outpouching of the bowel wall (a diverticulum) with hypoechoic wall thickening (5–18 mm thickness) of the affected segment, sometimes with hyperechoic fecalith (arrow) or gas echoes inside. Often echogenic noncompressible fat that is surrounding at least one diverticulum, indicating an inflammatory process. Additional supportive findings can also be identified on ultrasound, including pericolonic abscess or free intraperitoneal air in complicated cases. While CT is traditionally considered superior over ultrasound for the accuracy in diagnosis of diverticulitis, ultrasound can still be a useful modality that might aid in early diagnosis or be utilized in resource-limited situations. When performed by an experienced operator, the sensitivity and specificity have reached greater than 80% in past studies, but newer studies show an improvement in the accuracy that are increasingly close to CT.

The differential for acute diverticulitis includes colitis, ruptured appendicitis, and sigmoid volvulus. The sonographic appearance of colitis includes bowel wall thickening >3 mm with echogenic pericolic fat without the outpouching of bowel wall seen in diverticulitis. Perforated appendicitis, in addition to the standard appendicitis findings, may also demonstrate a complex or loculated periappendiceal fluid collection or abscess, dilated bowel loops, and increased hepatic periportal echogenicity. Sigmoid volvulus may be difficult to visualize with ultrasound secondary to signal attenuation from the gas-filled volvulus, and so plain films or CT may be considered for this diagnosis (Figure 17.22).

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Keywords/Tags: Diverticulitis

Learning Point 22: Acute diverticulitis can be identified as an outpouching with hypoechoic wall thickening

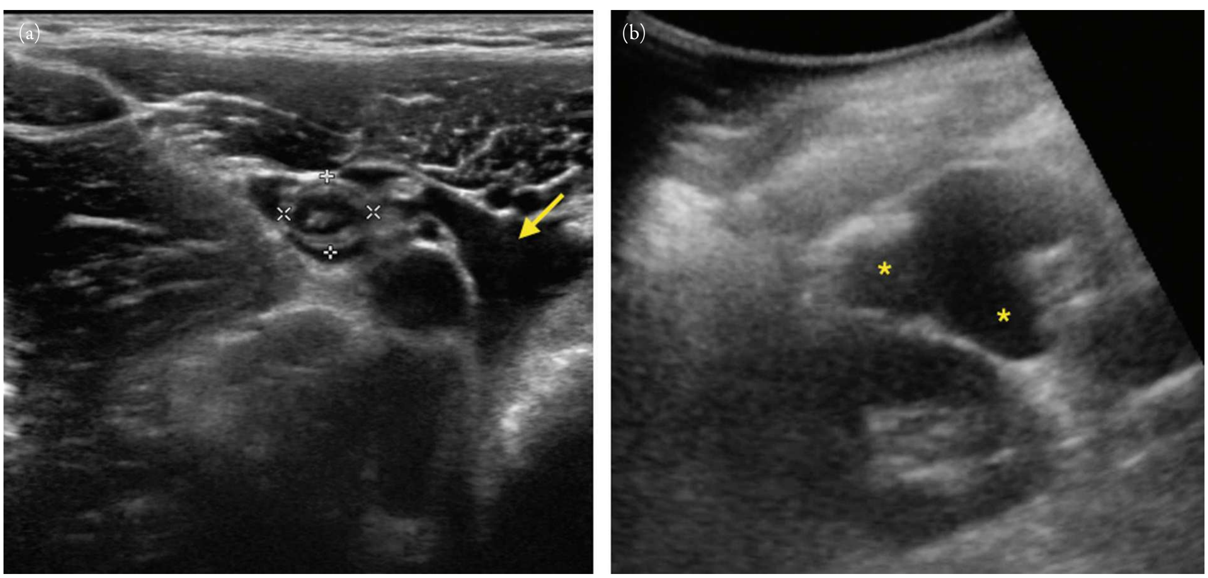

Figure 17.22 **Sonographic appearance of perforated appendicitis (a) and colitis (b).** Note the fluid surrounding (arrow) surrounding the appendix, which is seen in transverse axis. Large bowel can be differentiated from small bowel by the haustra (*), or sacculations, formed along the taenia coli, the band of smooth muscle that runs in longitudinal direction with the colon. Small bowel features valvulae conniventes (aka plicae circulares) that appear as circumferential bands around the bowel.

(5–18 mm thickness) of the affected segment, sometimes with hyperechoic fecalith or gas echoes inside.

23. EXPLANATION

A. Apply color Doppler to SMA to evaluate blood flow. The SMA is the vessel most likely to be affected by mesenteric ischemia. Though mesenteric ischemia is difficult to diagnose with ultrasound, with angiography being the gold standard, knowledge of sonographic findings can aid in diagnosis. While the sonographic findings in mesenteric ischemia are nonspecific, they include thickening of the small bowel associated with intraperitoneal fluid. It may be challenging to identify because of excessive bowel gas from an accompanying ileus, but if SMA occlusion is suspected, color Doppler may be used to evaluate blood flow through the main trunk of the SMA (Figure 17.23a, Video 17.6). Mesenteric artery duplex assessments are made in a sagittal plane using color as well as pulsed wave doppler and consist of peak systolic velocity (PSV) evaluation (Figure 17.23b). The SMA is evaluated within 2 cm of the aorta and the celiac artery within 1 cm. Normal PSV values range from 80 to 200 cm/s for the SMA and 90 to 190 cm/s for the celiac artery, with elevated PSV indicating stenosis and depressed PSV indicating occlusion.

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Keywords/Tags: Mesenteric ischemia

Learning Point 23: Sonographic findings in mesenteric ischemia are nonspecific; they include thickening of the small bowel associated with a significant amount of intraperitoneal fluid. It may be challenging to identify because of excessive bowel gas from an accompanying ileus, but if superior mesenteric artery (SMA) occlusion is suspected, color Doppler may be used to evaluate blood flow through the main trunk of the SMA.

24. EXPLANATION

B. Linear. Ultrasound is a valuable tool in the evaluation of inguinal hernias, with a sensitivity of 97%, specificity of 85%, and positive predictive value of 93%. To obtain the best sonographic images, use a high-frequency linear probe to provide more detail and better visualization of a peritoneal defect and bowel wall layers. In the evaluation for hernia, the peritoneal defect is usually at the point of pain, and it is important to evaluate the defect from several angles and record bowel movement or its absence through the defect. An adequate amount of gel should be utilized when evaluating a hernia to avoid contact artifact. In patients with a larger body habitus or significant subcutaneous fat at the site requiring investigation, a curvilinear

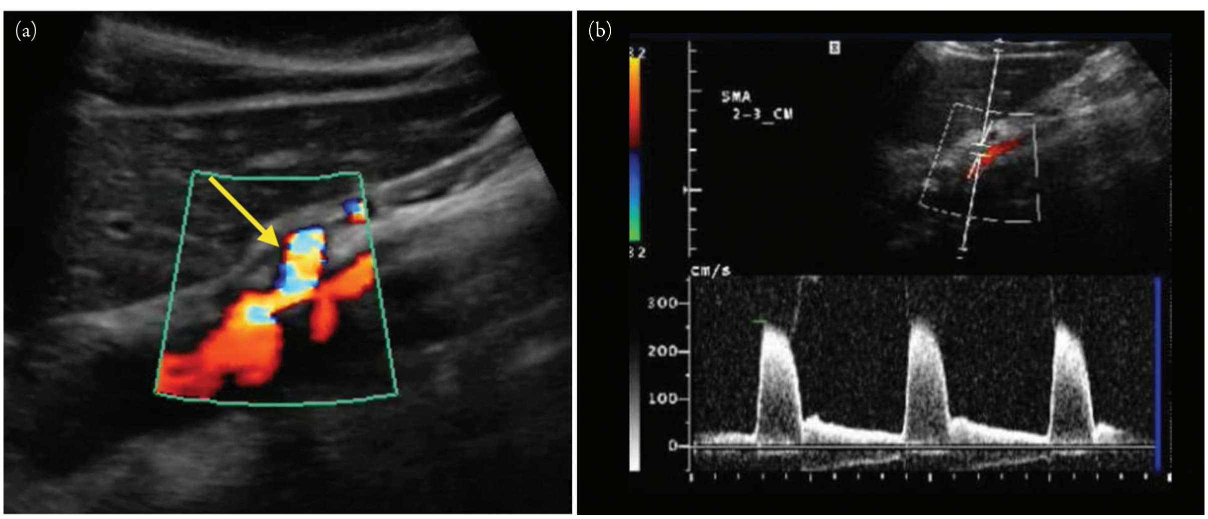

Figure 17.23 (a) **Longitudinal axis view of the aorta with the superior mesenteric artery (SMA) take-off.** Color Doppler reveals some aliasing that is suggestive of SMA stenosis and mesenteric ischemia. When this is suggested, pulsed-wave Doppler should be used to evaluate the peak systolic velocity of the SMA to determine the presence of stenosis. (b) **Spectral waveform of celiac and superior mesenteric arteries, with normal ranges for peak systolic velocity.**

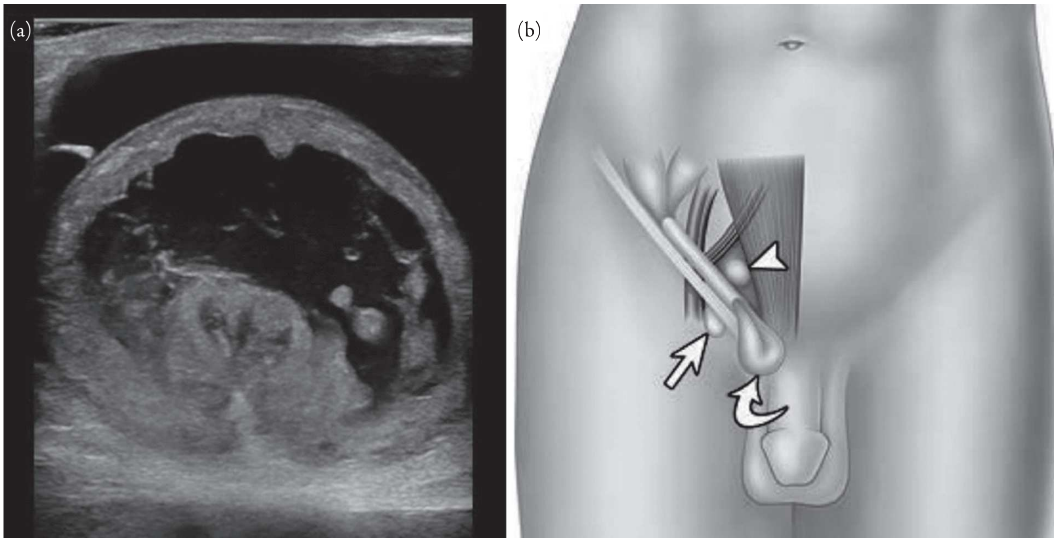

Figure 17.24 **Incarcerated hernia with bowel wall thickening, echogenic fat, and free fluid.** (b) **Location of groin hernias.** Direct inguinal hernias (arrowhead) originate in Hesselbach's triangle, which is bordered by the rectus muscle medially, inferior epigastric vessels superiorly, and inguinal ligament inferiorly. Indirect inguinal hernias (curved arrow) travel in the inguinal canal and are visualized in the scrotum. Femoral hernias (straight arrow) originate in the femoral canal just lateral and inferior to the inguinal ligament. Adapted from Figure 6 of Jacobson, JA, Khoury V, Brandon CJ. Ultrasound of the groin: techniques, pathology, and pitfalls. *AJR Am J Roentgenol.* 2015;205:513–523.

probe may be necessary to better optimization. If there is still high clinical suspicion despite a nondiagnostic ultrasound, MRI is the gold standard for diagnosis of occult inguinal hernias.

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Keywords/Tags: Hernia

Learning Point 24: Hernias are best visualized with a linear, high-frequency probe, for optimal visualization of peritoneal defect and bowel wall layers.

25. EXPLANATION

A. Reverberation artifact. Pneumoperitoneum classically presents on ultrasound with the peritoneal stripe sign. This in fact is a type of reverberation artifact that is derived from multiple reflections of the peritoneum, comparable to A lines in the lung. The subphrenic air that appears as an echogenic line with ring-down artifact or extraluminal air shadowing on ventral surface of the liver needs to be differentiated from gas in GI lumen or lung to avoid a false diagnosis of pneumoperitoneum. Intraperitoneal air can appear as a dirty shadow that obscures visualization of deeper abdominal organs, but it can also appear as small hyperechoic foci of air bubbles

Figure 17.25 **Pneumoperitoneum stripe sign.** Reverberation artifact from skin to peritoneum causes the stripe sign seen here (arrow). These should appear similar to A-lines on thoracic ultrasound. From Figure 94.5 of Levy A, Pneumoperitoneum. In: Levy A, Koenraad JM, Yeh BM, eds. *Gastrointestinal Imaging.* New York, NY: Oxford University Press, 2015.

within intraperitoneal free fluid. A linear high-frequency probe is recommended with the most optimal placement being in the right hypochondrium or epigastrium with the patient in the supine position and thorax slightly elevated. (See Figure 17.25.)

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Keywords/Tags: Pneumoperitoneum

Learning Point 25: Pneumoperitoneum can be recognized with the peritoneal strip sign.

18.

MUSCULOSKELETAL ULTRASOUND

Raffi Salibian and Antoinette Roth

QUESTIONS

1. A 50-year-old male presents with anterior shoulder pain. You elicit a positive Yergason test. Pathology of the long head of the biceps tendon is suspected. Gray scale imaging of the biceps tendon in the transverse plane is shown in Figure 18.1.

What is the best way to determine if this finding is real or artifactual?

A. Angle the transducer to ensure that the ultrasound beam is directed perpendicular to the biceps tendon
B. Angle the transducer to ensure that the ultrasound beam is directed parallel to the biceps tendon
C. Angle the transducer to ensure that the ultrasound beam is directed 45 degrees to the tendon
D. Use color Doppler to evaluate the tendon

2. A 45-year-old man presents with acute onset knee pain, swelling, and erythema. He denies any trauma. His exam elicits tenderness with both passive and active range of motion, as well as axial loading. What is the best location for evaluating a knee joint effusion? Which anatomic landmarks are used to identify knee joint fluid in this location?

A. Suprapatellar recess, between quadriceps and prefemoral fat pads
B. Medial knee, between superficial and deep bands of the medial collateral ligament
C. Posteromedial knee, between medial head of gastrocnemius muscle and semimembranosus muscle
D. Lateral knee, between iliotibial band and the distal femur

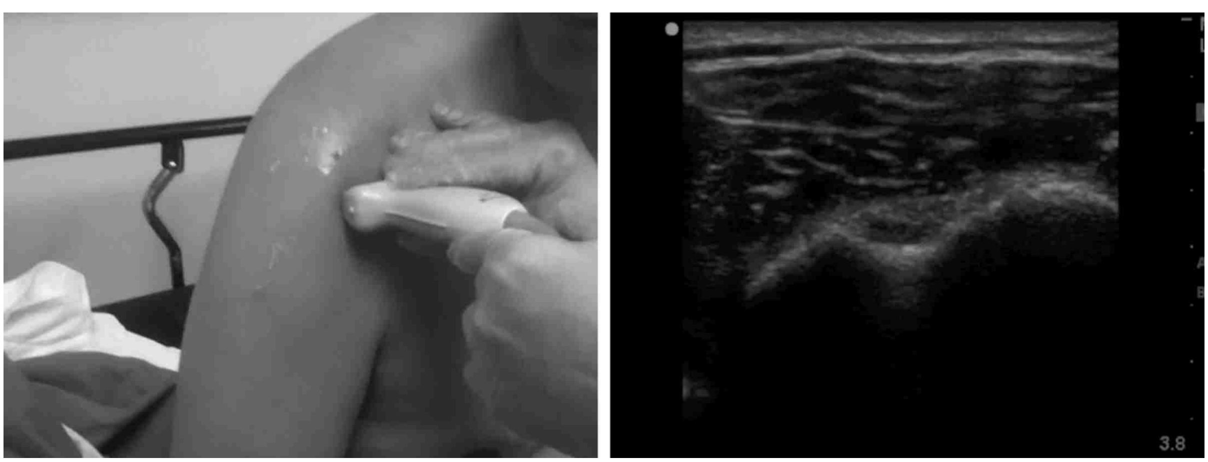

Figure 18.1

3. A 60-year-old woman presents with elbow pain after a fall. Radiograph shows no obvious elbow fracture. The lateral projection of the elbow is poorly positioned and evaluation for joint effusions is limited. What is the most sensitive location for identifying an elbow joint effusion with ultrasound?

A. Anterior coronoid recess of the distal humerus
B. Annular recess of the elbow joint
C. Medial elbow deep to the common flexor tendon
D. Posterior olecranon recess of the distal humerus

4. A 67-year-old woman presents with acute ankle pain, swelling, and erythema. She denies any recent injury or prior episodes. Exam shows asymmetric swelling to the right ankle as well as tenderness to both malleoli. Joint infection is suspected. What is the best approach for identifying an ankle joint effusion?

A. Posterior ankle approach
B. Medial ankle approach
C. Lateral ankle approach
D. Anterior ankle approach

5. A 43-year-old man with a history of diabetes presents with left hip pain for the past week. The patient recently had pyelonephritis. He has tenderness elicited with both active and passive range of motion. Joint infection is suspected. What is the measurement of the anterior recess of the hip joint, along the femoral neck, that indicates a hip joint effusion? What type of transducer is typically used to evaluate the hip joint?

A. 20 mm, curvilinear transducer
B. 50 mm, linear transducer
C. 8 mm, curvilinear transducer
D. 1 mm, linear transducer

6. A 60-year-old woman presents with a posterior knee mass. What are the key anatomic landmarks for identifying a popliteal cyst?

A. Popliteal cysts occur in the posterolateral knee between medial and lateral heads of gastrocnemius.
B. Popliteal cysts occur in the posteromedial knee between medial head of the gastrocnemius and the semimembranosus.
C. Popliteal cysts occur in the medial knee between the deep and superficial bands of the medial collateral ligament.
D. Popliteal cysts occur in the lateral aspect of the knee deep to the iliotibial band.

7. A 33-year-old female house cleaner presents with anterior knee pain and swelling superficial to the patella. What are the three anterior knee bursae that are commonly inflamed?

A. Suprapatellar, retropatellar, infrapatellar
B. Suprapatellar, prepatellar, superficial infrapatellar
C. Prepatellar, superficial infrapatellar, deep infrapatellar
D. Retropatellar, superficial infrapatellar, deep infrapatellar

8. A 58-year-old man presents with bilateral posterior elbow soft tissue swelling, erythema, and pain. He has no history of elbow injury. Three years ago the patient had an episode of acute left great toe pain, swelling, and erythema in the region of the 1st metatarsophalangeal joint that resolved with nonsteroidal anti-inflammatory drugs. What is the most likely diagnosis?

A. Olecranon bursitis related to gout
B. Olecranon bursitis related to rheumatoid arthritis
C. Olecranon bursitis related to chronic repetitive trauma
D. Olecranon bursitis related to acute infection

9. A 46-year-old male presents with acute onset knee pain and swelling. The patient may have a history of gout. What is the typical pattern of crystal deposition in cartilage with gout?

A. Crystal deposition within the cartilage
B. Crystal deposition on the cartilage surface
C. Crystal deposition in cartilage can't be seen with ultrasound
D. Crystal deposition between cartilage and subchondral bone

10. A 56-year-old female presents with chronic posterior ankle pain for several months. There is no history of trauma. On exam, she appears comfortable and has normal vital signs. She has tenderness to the distal calf but no malleolar tenderness. Ankle radiograph shows a large posterior superior calcaneal spur with soft tissue thickening in the region of the distal Achilles tendon. Small calcifications seen in the region of the distal Achilles tendon. What is the most likely diagnosis?

A. Acute Achilles tendon rupture
B. Isolated retrocalcaneal bursitis
C. Chronic Achilles tendinopathy
D. Calcaneal stress fracture

11. A 24-year-old man presents with pain in the region of the Achilles tendon after playing basketball. Ultrasound shows a diffusely thickened and hypoechoic Achilles tendon. A focal defect in the Achilles tendon is suspected near the calcaneus insertion. What is the best way to distinguish a partial from a complete Achilles tear?

A. Use color Doppler to evaluate the tear
B. Use harmonics to evaluate the tear
C. Use dynamic maneuvers with ultrasound imaging
D. Compare with the contralateral asymptomatic side

12. A 33-year-old woman presents with left 4th finger pain and swelling for 5 days. A radiograph shows diffuse finger soft tissue swelling without bone erosions or other arthritis. Ultrasound of the finger shows severe diffuse distention of the 4th finger flexor tendon sheath. The finger flexor tendons are normal. The patient is afebrile with normal white blood cell count. She also reports having white scaly plaques on the extensor surfaces of her elbows. What is the most likely diagnosis?

A. Fourth finger flexor tenosynovitis from acute trauma
B. Finger tenosynovitis related to psoriatic arthritis (sausage digit)
C. Infectious finger tenosynovitis related to tuberculosis
D. Finger flexor tendinopathy from chronic repetitive injury

13. A 60-year-old male presents with chronic anterior shoulder pain over the long head of the biceps tendon. Pain is elicited when he tries to supinate his wrist against resistance when his elbow is flexed 90 degrees. Ultrasound shows distention of the biceps tendon sheath with simple appearing hypoechoic fluid. Ultrasound-guided injection is performed. Where should the injected material be deposited?

A. Inject into the biceps tendon itself
B. Inject into subacromial-subdeltoid (SA-SD) bursa
C. Inject into the biceps tendon sheath
D. Inject into the subcoracoid bursa

14. A 50-year-old woman has pain mainly with shoulder abduction. Radiograph shows moderate acromioclavicular joint osteoarthritis. External impingement is suspected. Ultrasound shows an intact rotator cuff with moderate volume fluid in the SA-SD bursa. Steroid and anesthetic injection of the bursa is performed. Where should the needle tip be placed to inject medicine into the SA-SD bursa?

A. Between the deltoid muscle and rotator cuff tendons
B. Between the subcutaneous soft tissue and the deltoid muscle
C. Between the rotator cuff tendons and humeral head
D. Inject medicine into the acromioclavicular joint

15. A 45-year-old woman presents with acute onset right shoulder pain and limited range of motion. There is no history of trauma. No other signs or symptoms of infection are noted. Ultrasound shows several small echogenic foci in the supraspinatus tendon. The supraspinatus tendon is enlarged and hypoechoic without focal tendon defects. Minimal adjacent SA-SD bursa fluid is noted. What is the most likely diagnosis?

A. Glenohumeral joint osteoarthritis
B. Deltoid muscle rupture with hematoma
C. External impingement with rotator cuff tear
D. Calcific tendinosis with SA-SD bursitis

16. A 50-year-old man presents with a painless dorsal forefoot soft tissue mass that has been slowly growing for the past 6 months. On physical exam the mass is soft, mobile, and compressible. Simple ganglion cyst is suspected. What are the key features of simple cystic structures on ultrasound?

A. Anechoic with posterior acoustic enhancement
B. Echogenic with posterior acoustic shadowing
C. Echogenic with posterior acoustic enhancement
D. Hypoechoic with posterior acoustic shadowing

17. A 39-year-old female intravenous drug user presents with distal arm pain and swelling. Ultrasound shows a complex heterogeneous subcutaneous soft tissue mass concerning for an abscess. What is the typical appearance of an abscess on ultrasound?

A. Irregular hypoechoic or echogenic mass without internal flow
B. Well circumscribed anechoic mass without internal flow
C. Solid echogenic mass with internal flow
D. Circumscribed hypoechoic mass with echogenic hilum

18. A 33-year-old woman presents with multiple palpable masses in the right volar mid-forearm region. The masses have been present for 8 years. The masses are not painful and are not growing. On physical exam the masses are soft, mobile, and compressible. The patient has no known history of malignancy. What is the most likely diagnosis?

A. Metastatic disease to the soft tissues
B. Low-grade lipomatous lesions like simple lipomas
C. Multiple benign forearm lymph nodes
D. Multiple forearm abscesses

19. A 60-year-old woman presents with enlarging painful right arm soft tissue mass for 6 months. There is no history of trauma to this region nor any signs or symptoms of infection. The mass feels firm and is not easily compressible on physical exam. A soft tissue sarcoma is suspected. What is the typical ultrasound appearance of a soft tissue sarcoma?

A. Anechoic mass without internal flow
B. Solid heterogeneous mass with internal flow
C. Hypoechoic mass with mobile debris and no internal flow
D. Circumscribed hypoechoic mass with echogenic hilum

20. A 60-year-old woman presents with an enlarging soft tissue mass. Grayscale ultrasound images show a circumscribed hypoechoic subcutaneous soft tissue mass. Soft tissue sarcoma is suspected, and the mass is growing and painful. What is the next best step?

A. Percutaneous biopsy of the lesion for definitive diagnosis
B. Plain radiograph of the region of interest
C. MRI with contrast of the soft tissue mass
D. Color and spectral Doppler evaluation of the mass

21. A 55-year-old man presents with a slowly enlarging arm soft tissue mass. On palpation, it is superficial, nodular, fixed, and nontender. Ultrasound shows extensive posterior acoustic shadowing in the region of the mass. The mass is largely obscured by this artifact. What is the next best imaging modality to evaluate this mass?

A. Ultrasound with color Doppler
B. Plain radiograph of the arm
C. MRI of the arm with contrast
D. Nuclear medicine bone scan

22. A 50-year-old woman presents with pain and paresthesia in the distribution of the median nerve in the hand. What is the typical appearance of the median nerve in carpal tunnel syndrome?

A. Enlarged and hyperechoic just proximal to site of impingement
B. Enlarged and hypoechoic just proximal to site of impingement
C. Flattened and hyperechoic just proximal to site of impingement
D. Flattened and hypoechoic just proximal to site of impingement

23. A 23-year-old woman presents with foreign body sensation to the heel. The patient reports stepping on a sharp tree branch. A retained foreign body is suspected. No foreign body is seen on ankle radiographs. Ultrasound identifies a 10 mm linear echogenic foreign body in the subcutaneous soft tissues of the heel. What type of foreign bodies are usually not seen on radiographs?

A. Wood and metal
B. Wood and plastic
C. Glass and metal
D. Glass and wood

24. A 60-year-old woman presents with chronic posterior inferior heel pain near the calcaneal origin of the plantar aponeurosis. Plantar fasciitis is suspected. What is the typical appearance of the plantar fascia in patients with plantar fasciitis?

A. Echogenic thickened plantar fascia (>10 mm)
B. Hypoechoic thickened plantar fascia (>10 mm)
C. Hypoechoic thickened plantar fascia (>4 mm)
D. Echogenic attenuated plantar fascia (<5 mm)

25. A 65-year-old woman presents with difficulty extending the left third finger. The finger occasional gets locked in flexion and then with a painful snapping sensation goes into extension. What is the most likely diagnosis, and which structure is commonly implicated in this disease?

A. Septic arthritis, metacarpophalangeal joint
B. Trigger finger, thickening of the A1 pulley
C. Hypoechoic thickened plantar fascia (>4 mm)
D. Echogenic attenuated plantar fascia (<5 mm)

26. A 17-year-old female presents to the emergency department with acute distal left forearm pain after a fall. The distal wrist and forearm are painful and swollen. No obvious osseous deformity is detected. Bedside ultrasound of the forearm is performed to evaluate for a fracture. What is the typical sonographic appearance of a long bone extremity fracture?

A. Focal disruption or discontinuity of the echogenic bone cortex
B. Hypoechoic soft tissue mass near the bone cortex without internal flow with color Doppler evaluation
C. Increased echogenicity in the central bone marrow space
D. Hypoechoic soft tissue mass near the bone with internal flow demonstrating a ying-yang appearance during color Doppler evaluation

27. A 40-year-old male presents to the emergency department with acute shoulder pain after a motorcycle accident. The left shoulder is swollen and painful, and the patient is not able to range the shoulder. Ultrasound of the shoulder is performed prior to plain radiography. Transverse grayscale image acquired from the posterior aspect of the shoulder is shown in Figure 18.2.

What is the diagnosis?

A. Posterior humeral head dislocation
B. Complete full-thickness supraspinatus tendon tear
C. Anterior humeral head dislocation
D. Large glenohumeral joint effusion

Figure 18.2

ANSWERS

1. EXPLANATION

A. Angle the transducer to ensure that the ultrasound beam is directed perpendicular to the biceps tendon. Anisotropy occurs when the majority of the ultrasound beam returning from a tendon does not reach the transducer. This artifact occurs when the beam originating from the transducer is not directed perpendicular to the tendon of interest. Normal tendons are typically bright or echogenic on ultrasound. Anisotropy can result in a dark or hypoechoic appearing tendon. This can result in the incorrect diagnosis of tendinopathy or tendon tearing. Angling the transducer to achieve the optimal perpendicular orientation of the ultrasound beam to the tendon of interest can address this artifact (Figure 18.3). If a symptomatic tendon remains hypoechoic after adjusting the ultrasound beam for anisotropy, tendinopathy or tearing should be considered.

Learning Points: Anisotropy is a common artifact seen in musculoskeletal ultrasound. Anisotropy is most commonly encountered when imaging tendons and may lead to an incorrect diagnosis of tendinopathy.

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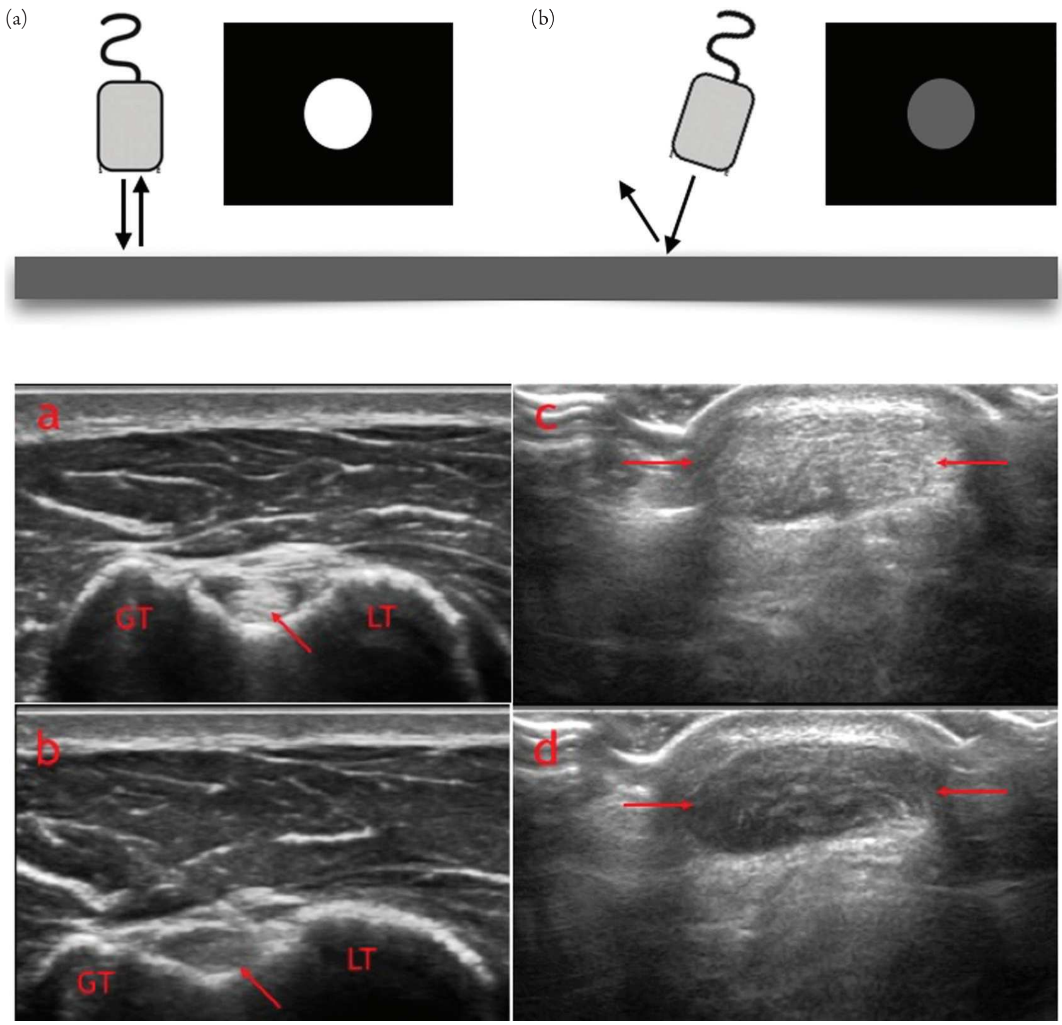

Figure 18.3 **Illustration of anisotropy in musculoskeletal ultrasound.** When the sound beam is perpendicular to the structure, the majority of the echos return to the probe, leading to accurate imaging of the structure. When the sound beam is off perpendicular, the echos deflect away from the probe, leading to an artifactually anechoic or hypoechoic space (schematic images (a) and (b)). Grayscale sonographic images in transverse plane of the long head of the biceps tendon (arrow) and of the Achilles tendon (between arrows) with the ultrasound beam directed perpendicular to the tendons (sonographic images a and c respectively). The tendons have a normal echogenic appearance. When the ultrasound beam is not directed perpendicular to a tendon, the tendons become artifactually hypoechoic (sonographic images b and d).

Keywords/Tags: Biceps tendon, Achilles tendon, anisotropy

2. EXPLANATION

A. Suprapatellar recess, between quadriceps fat pad and prefemoral fat pad. Knee joint effusion is best seen in the suprapatellar recess of the knee. Mandl (2012) found that a suprapatellar window of a knee flexed at 30 degrees provided the best sensitivity for detecting knee effusions. Knee joint fluid accumulates between the quadriceps and prefemoral fat pads (Figure 18.4). A lateral suprapatellar approach is typically used for ultrasound-guided aspiration of the knee joint when infection or crystal deposition disease is suspected.

Learning Points: Knee joint effusion is best seen in the suprapatellar recess of the knee. Joint fluid accumulates between the quadriceps fat pad and the prefemoral fat pad.

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Keywords/Tags: Knee joint effusion, knee joint aspiration

3. EXPLANATION

D. Posterior olecranon recess of the distal humerus. The posterior olecranon recess of the distal humerus is the most sensitive location for identifying an elbow joint effusion. Hypoechoic joint fluid in the olecranon recess posteriorly displaces the echogenic fat pad that normally resides in the olecranon recess. Recall that in an adult after trauma, an elbow joint effusion without radiographic evidence of fracture, indicates an occult radial head fracture. In a pediatric patient with an elbow injury but with a negative X-ray, an elevated fat pad is associated with a nondisplaced supracondylar fracture. Aspiration of the elbow joint is typically performed from a posterolateral approach with needle placement into the olecranon recess (Figures 18.5, 18.6).

Learning Points: Posterior olecranon recess of the distal humerus is the most sensitive location for identifying an elbow joint effusion.

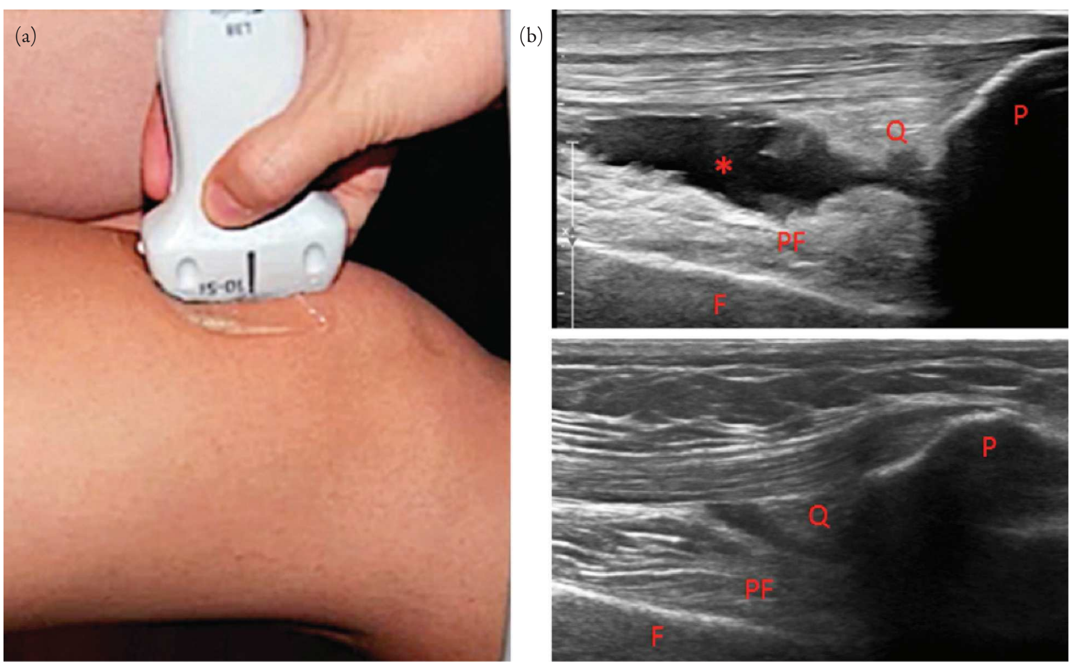

Figure 18.4 **Placement of the transducer to image the suprapatellar recess.** (a) Note that the probe indicator is pointed cephalad and that the knee is slightly flexed to about 30 degrees. (b) Top panel is a grayscale sonographic image in longitudinal plane of the suprapatellar recess of the knee joint with a moderate volume joint effusion. Hypoechoic joint fluid (*) accumulates between the quadriceps (Q) fat pad and prefemoral (PF) fat pad. The patella (P) and distal femur (F) are also seen. Botton panel shows a grayscale sonographic image in longitudinal plane of the suprapatellar recess of the knee with a physiologic volume of joint fluid between the quadriceps (Q) and prefemoral (PF) fat pads.

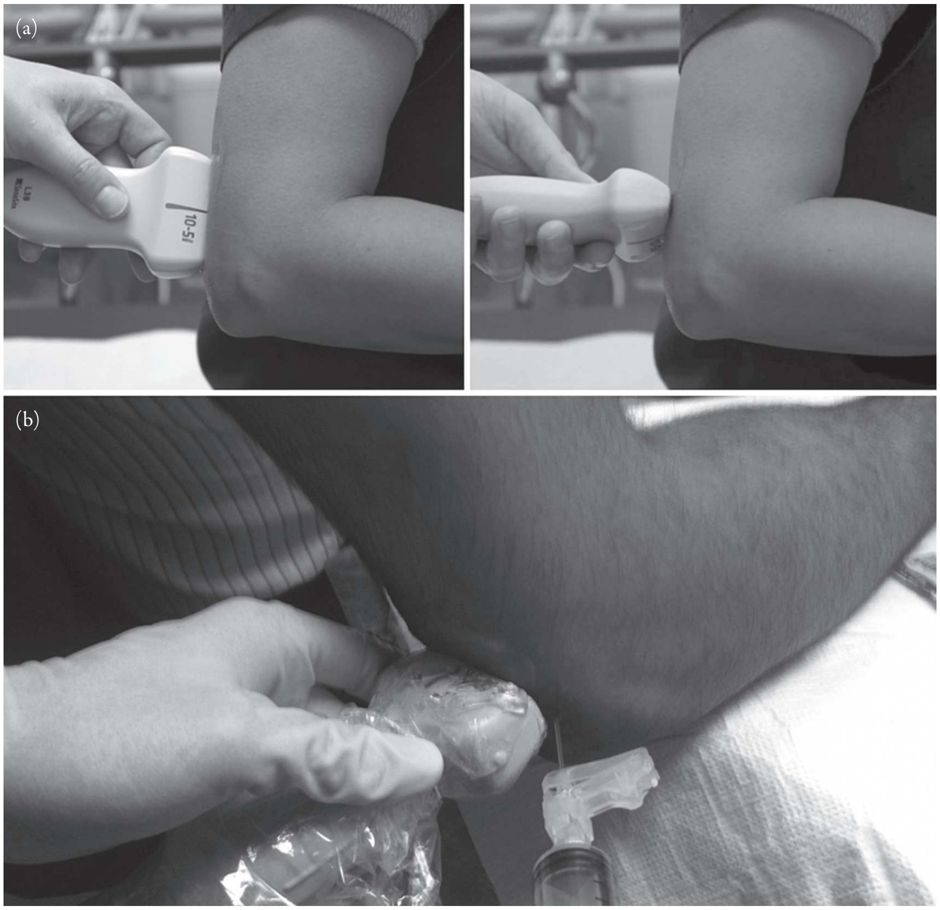

Figure 18.5 (a) **Placement of the transducer to obtain a long axis (left) and short axis (right) view of the olecranon fossa and posterior fat pad.** (b) **Placement of the transducer and needle insertion on a posterior-lateral approach to elbow arthrocentesis.**

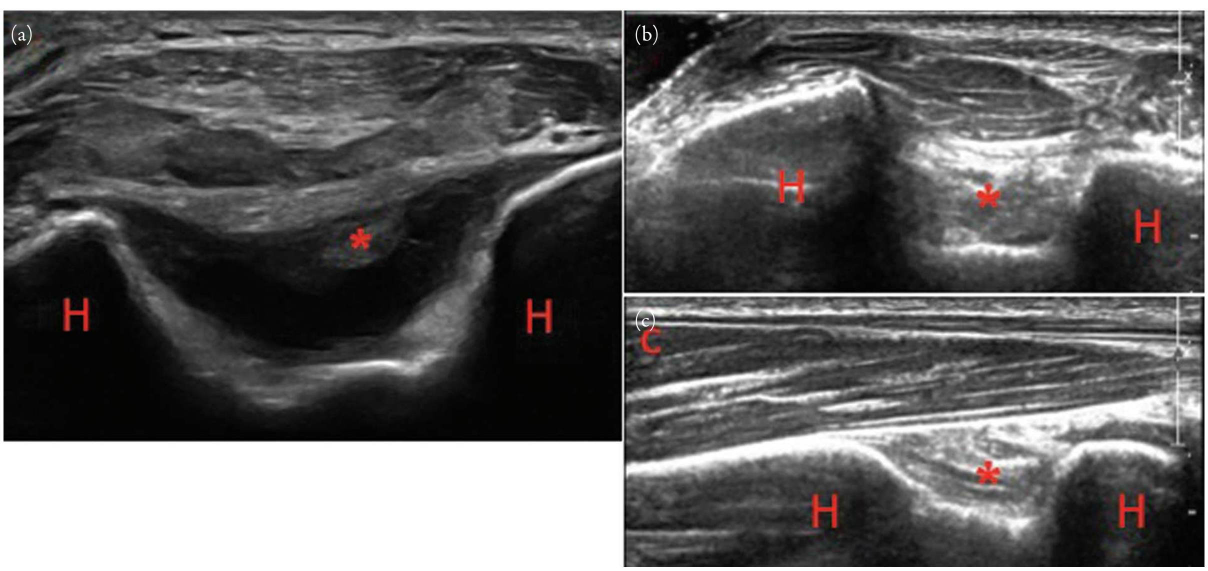

Figure 18.6 Panel (a) shows a transverse image of the posterior elbow in the region of the olecranon fossa of the distal humerus (H) showing anechoic elbow joint fluid posteriorly displacing the echogenic posterior elbow fat pad (*). Panels (b) and (c) show transverse and longitudinal planes of a normal elbow without effusion, respectively. The echogenic posterior elbow fat pad (*) is not displaced on these images.

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Keywords/Tags: Elbow joint effusion, elbow joint aspiration, olecranon fossa

4. EXPLANATION

D. Anterior ankle approach. The anterior tibiotalar joint recess is the most sensitive location for identifying an ankle joint effusion. The bony landmarks of the anterior distal tibia and the anterior talus are located to identify the anterior tibiotalar joint recess where joint fluid typically accumulates (Figure 18.7). Diagnostic aspiration of the ankle joint is typically performed from the anterior approach with the needle tip directed from distal to proximal. Care is taken to identify and avoid the dorsalis pedis artery superficial to the anterior ankle joint recess.

Learning Points: The anterior tibiotalar recess is the most sensitive location for identifying an ankle joint effusion.

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Keywords/Tags: Ankle joint, ankle aspiration

5. EXPLANATION

C. 8 mm, curvilinear transducer. The anterior femoral head–neck junction is the most sensitive location to identify a hip joint effusion. A lower frequency curvilinear transducer is typically used to evaluate the hip joint to achieve adequate penetration of the ultrasound beam. The combination of the normal hip joint capsule and physiologic fluid near the femoral head–neck junction typically measures up to 8 mm. This includes the anterior and posterior layers of the hip joint capsule, each measuring up to 3 mm, and up to 2 mm of physiologic hip joint fluid. The joint capsule is hypoechoic on ultrasound and can mimic a joint effusion. As such, a hip joint effusion should not be reported on ultrasound unless the anterior hip joint recess measures greater than 8 mm. Hip aspiration is performed from an anterior approach with the needle tip directed toward the femoral head–neck junction (Figure 18.8, 18.9, 18.10).

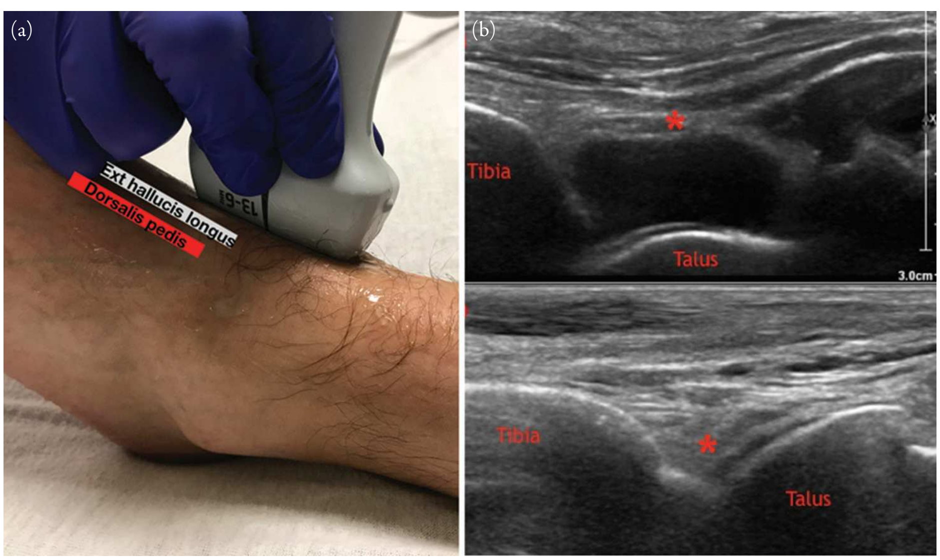

Figure 18.7 (a) **Placement of the transducer to image the anterior tibiotalar joint recess for arthrocentesis.** Note the location of the dorsalis pedis (red line), the extensor hallucis longus tendon (gray line), as well as the longitudinal orientation of the transducer. The needle is inserted caudally to cranially to allow in-plane visualization of the needle. (b) Top panel shows a longitudinal plane with anechoic fluid in the anterior recess of the tibiotalar joint. The joint effusion anteriorly displaces the echogenic fat pad (*) in this region. Bottom panel shows the anterior ankle in a patient without a joint effusion. The echogenic fat pad (*) is not displaced by joint fluid. The bony landmarks of the anterior distal tibia and the anterior talus are identified.

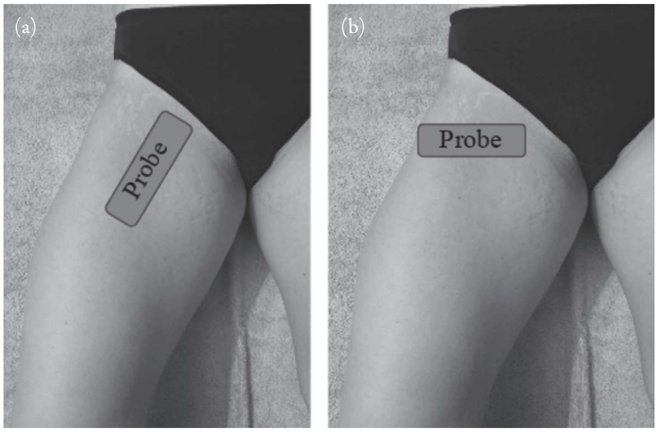

Figure 18.8 **Placement of the transducer to evaluate for hip joint effusion.** Longitudinal (Panel (a)) and transverse (Panel (b)) orientation of the ultrasound probe over the anterior hip to evaluate for a hip joint effusion. Notice that the hip is slightly abducted and internally rotated. The longitudinal plane is typically used for hip joint aspiration. The needle is inserted at the caudal aspect of the transducer and directed cranially parallel to the ultrasound probe.

Learning Points: Hip joint effusion is diagnosed when the anterior recess of the hip joint along the femoral neck measures greater than 8 mm.

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Keywords/Tags: Hip joint effusion, hip joint aspiration

6. EXPLANATION

B. Popliteal cysts occur in the posteromedial knee between medial head of the gastrocnemius and the semimembranosus. Popliteal or Baker's cysts occur between the medial head of the gastrocnemius muscle and the semimembranosus muscle (Figure 18.11). Statistically, most cystic appearing posterior knee masses are going to represent popliteal cysts. However, not all cystic appearing posterior knee

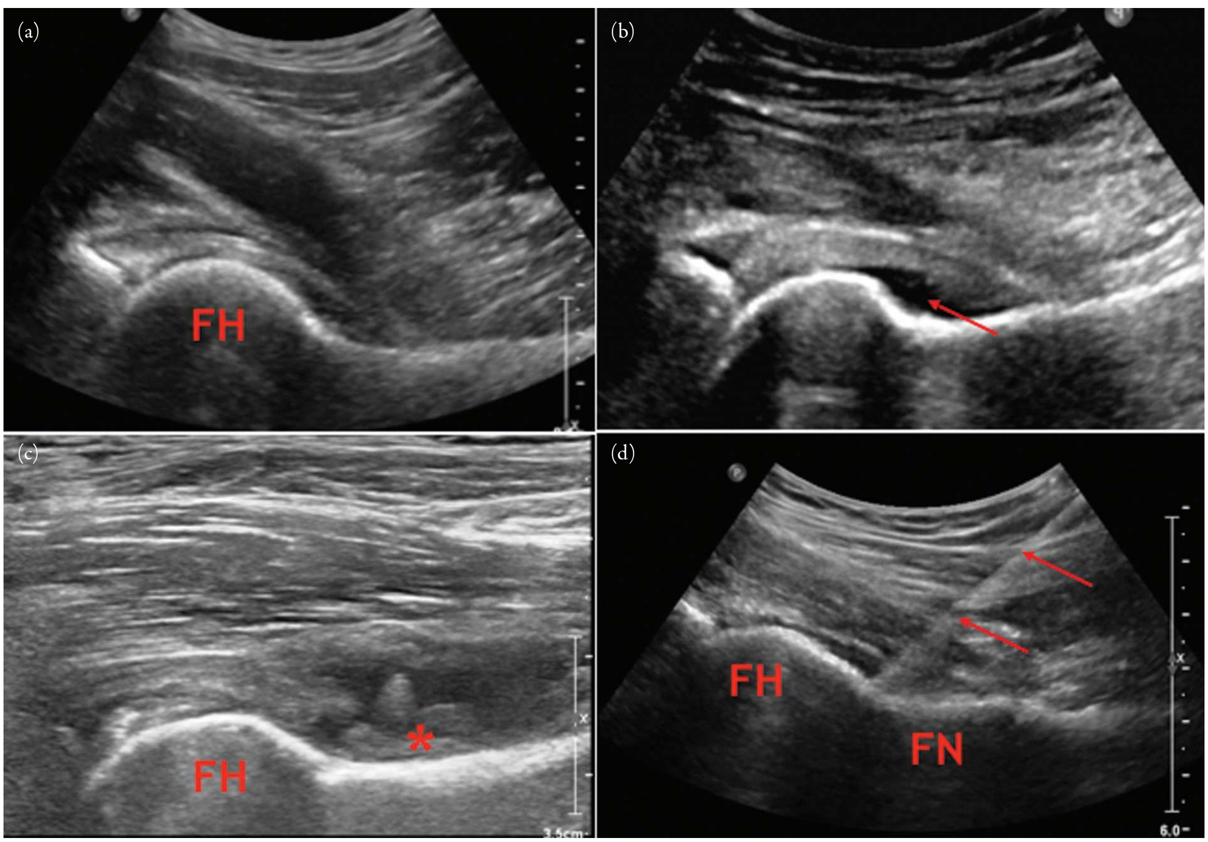

Figure 18.9 **Anterior hip ultrasound**. Panel (a) shows a grayscale sonographic image of the anterior hip joint recess in a patient without a hip joint effusion. In Panel (b) there is a small hip joint effusion, which appears as a region of anechoic fluid (arrow) anterior to the linear echogenic femoral cortex. Another patient with a small-moderate volume, complex hip joint effusion (Panel (c)) containing irregular echogenic debris (*) suggestive of synovitis. Panel (d) shows the tip of a 22-gauge spinal needle positioned at the femoral head-neck junction. This is the target site for the needle tip when performing diagnostic hip joint aspirations or therapeutic injections. All above images are grayscale ultrasound images of the anterior hip in the longitudinal plane.

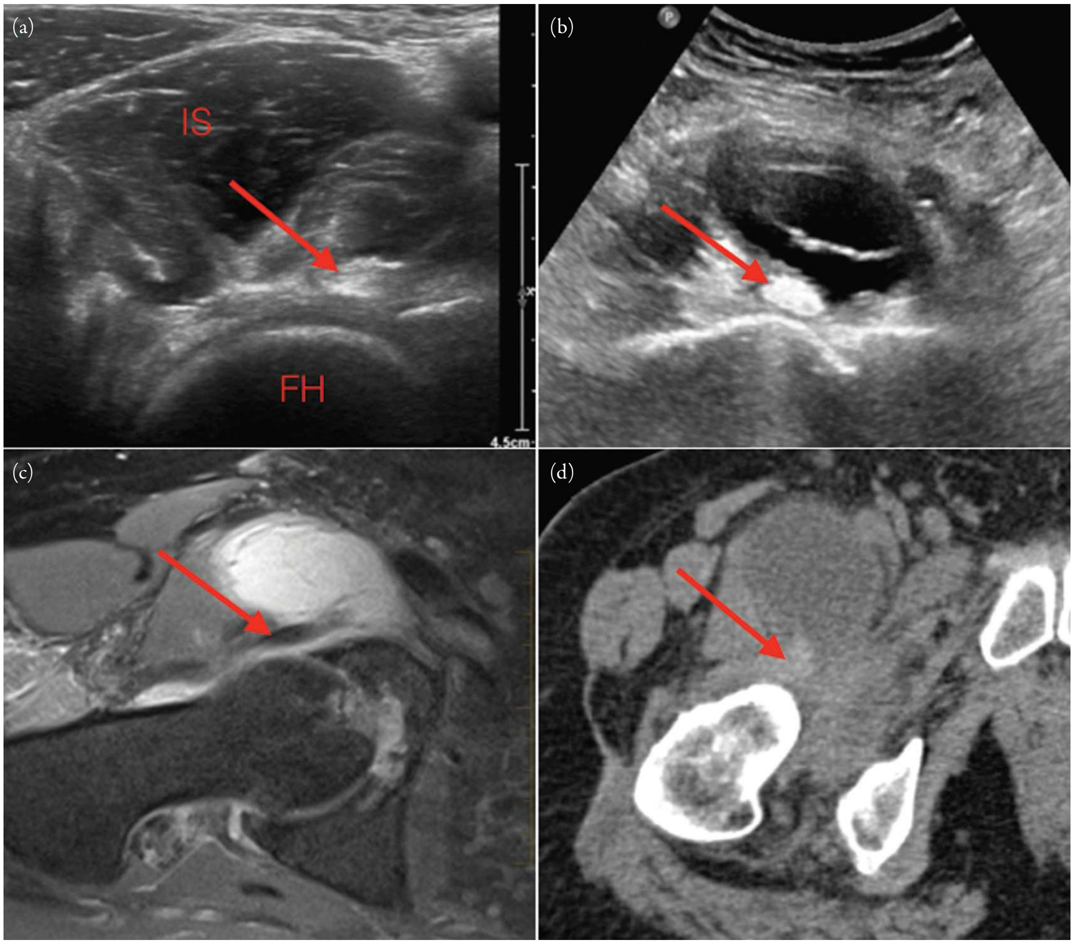

Figure 18.10 **Iliopsoas bursa**. This bursa is located anterior to the hip joint and communicates with the hip joint in up to 15% of normal asymptomatic individuals. Communication of this bursa with the hip joint is increased in the context of hip internal derangement as seen with any form of hip arthritis. On imaging, the iliopsoas bursa is typically located anterior to the hip joint and medial to the iliopsoas tendon. Panel (a) shows a grayscale sonographic image of the anterior hip in the transverse plane with a normal echogenic iliopsoas tendon (arrow). No iliopsoas bursal distention seen. Panel (b) is a grayscale ultrasound image of the anterior hip in the transverse plane showing a circumscribed mainly anechoic soft tissue mass with posterior acoustic enhancement and thin internal separations medial to the oval echogenic iliopsoas tendon (arrow). Axial magnetic resonance imaging (Panel (c)) and computed tomography (Panel (d)) images of the hip show a cystic appearing anterior hip soft tissue mass medial to the iliopsoas tendon (arrows). This mass is in the typical location of the iliopsoas bursa.

masses are popliteal cysts. Aneurysms related to the popliteal vessels and cystic appearing sarcomas can occur in the posterior knee region (Figure 18.12). A popliteal cyst cannot be definitively diagnosed without demonstrating the relationship of a cystic posteromedial knee mass to the muscles above.

Learning Points: Popliteal (aka Baker) cysts are located in posteromedial aspect of the knee between the medial head of the gastrocnemius tendon and the semimembranosus tendon.

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Keywords/Tags: Popliteal cyst, Baker's cyst

7. EXPLANATION

C. Prepatellar, superficial infrapatellar, deep infrapatellar. The prepatellar bursa is located anterior to the patella and proximal patellar tendon (Figure 18.14). The infrapatellar bursae are located deep and superficial to

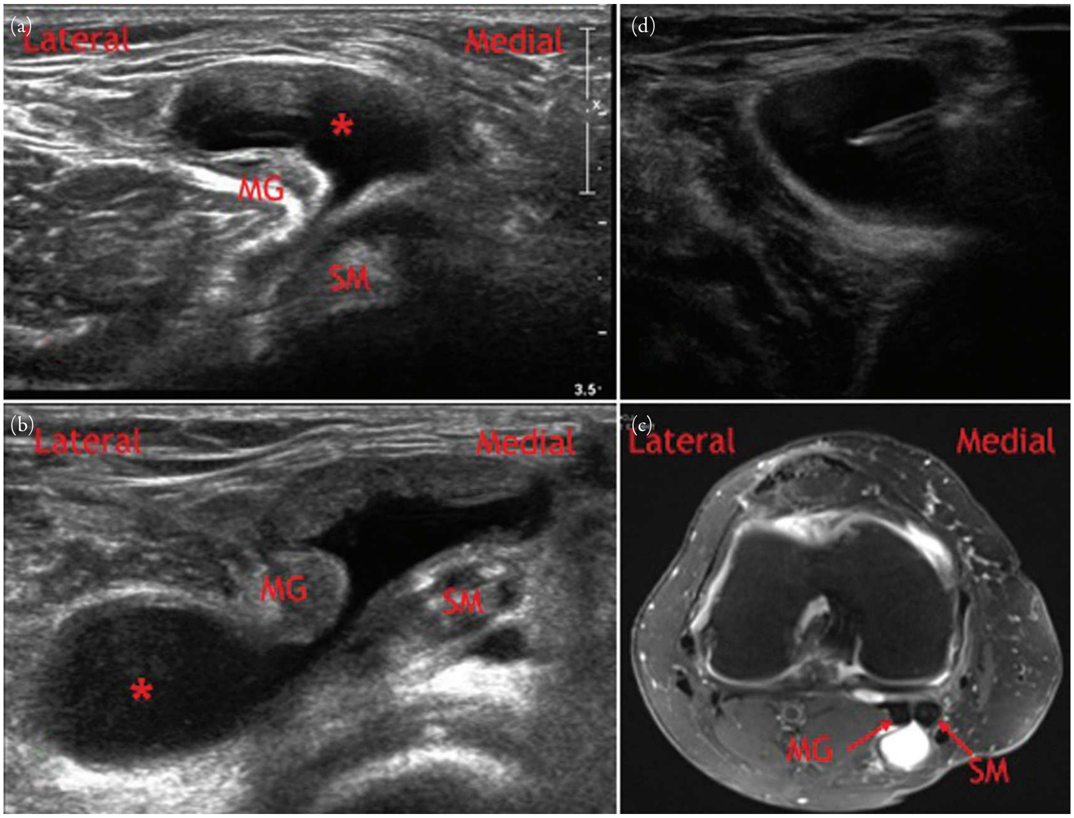

Figure 18.11 **Posterior knee masses.** Panels (a) and (b) show transverse planes of the posteromedial knee with hypoechoic fluid (*) extending between the medial head of the gastrocnemius muscle (MG) and the semimembranosus tendon (SM), respectively. This is consistent with a popliteal cyst. Panel (c) shows an axial magnetic resonance imaging fluid sensitive sequence with a popliteal cyst between the medial head of the gastrocnemius muscle (MG) and the semimembranosus tendon (SM). Panel (d) shows a linear echogenic needle tip seen entering a popliteal cyst during percutaneous cyst drainage.

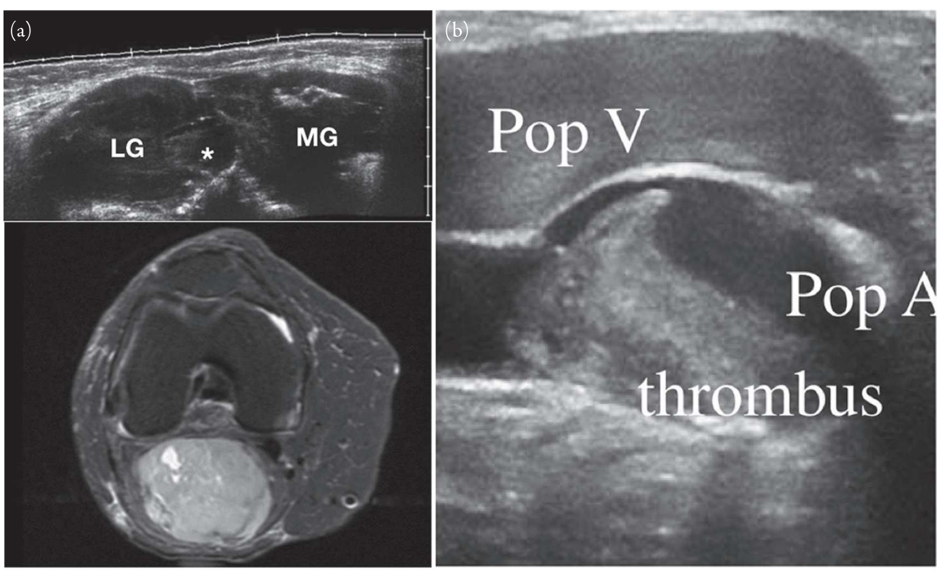

Figure 18.12 **(a) Popliteal sarcoma**. Top panel is a grayscale sonographic image of the posterior knee showing an echogenic solid-appearing soft tissue mass between the medial and lateral heads of the gastrocnemius muslce. Bottom panel shows the same soft tissue mass on MRI. Biopsy confirmed the diagnosis of popliteal fossa sarcoma. Adapted from Figures 1 and 4 of Raghupathi AK, Shetty A. Unusual presentation of popliteal soft tissue sarcoma: not every swelling in the knee is a Baker's cyst. *J Surg Case Rep*. 2013;2013(10):rjt074. **(b) Popliteal artery aneurysm**. Grayscale sonographic image in longitudinal plane of the posterior knee shows a popliteal artery aneurysm with intramural thrombus. The popliteal vein is seen superficial to the artery. From Figure 20 of Sprynger M, Rigo F, Moonen M, et al. Focus on echovascular imaging assessment of arterial disease: complement to the ESC guidelines (PARTIM 1) in collaboration with the Working Group on Aorta and Peripheral Vascular Diseases. *Cardiovasc Imaging*. 2018;19(11):1196–1220.

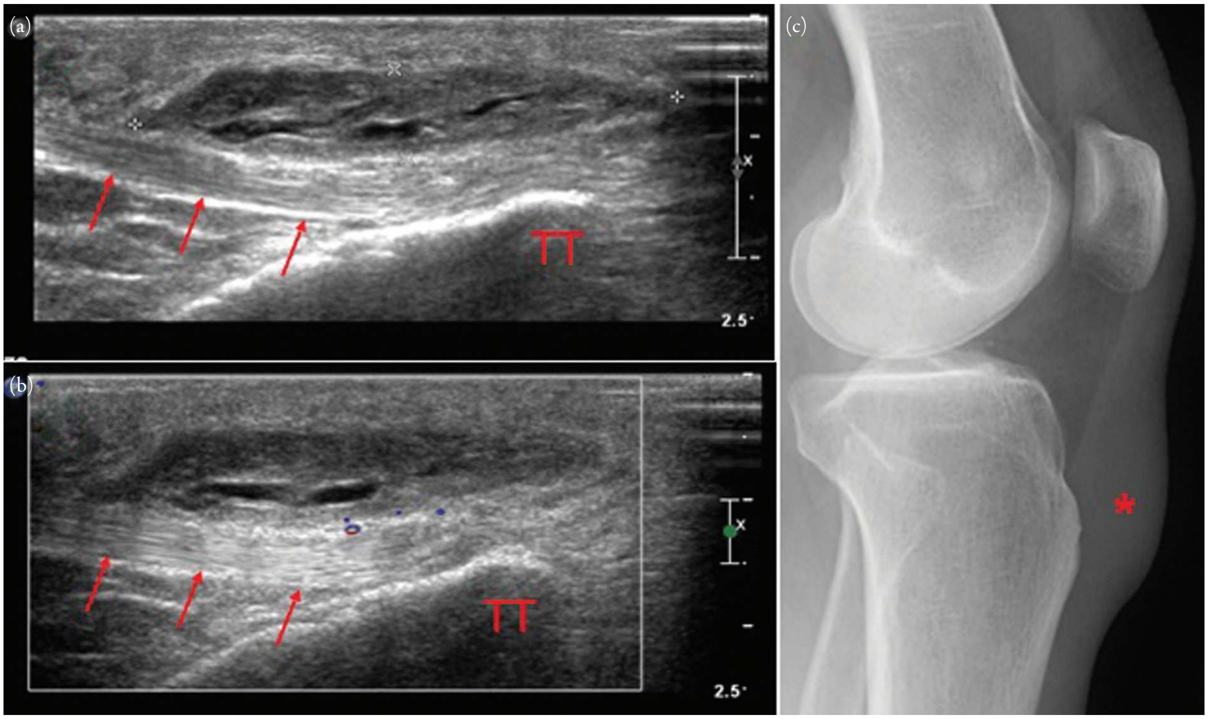

Figure 18.13 **Superficial infrapatellar bursitis.** Panels (a) and (b), respectively, show gray scale and color Doppler images in longitudinal plane of the anterior inferior knee with a subcutaneous soft tissue mass superficial to the distal patellar tendon (arrows = patellar tendon). The mass has no internal flow. Companion plain radiograph of the knee (Panel (c)) shows focal soft tissue swelling in the region of the superficial infrapatellar bursa (*) anterior to the tibial tuberosity.

the distal patellar tendon. Figure 18.13 shows an example of superficial infrapatellar bursitis. Bursal inflammtion in these regions can be seen with chronic repetative injury or with any synovial pathologic process including rheumatoid arthritis and gout.

Learning Points: Knee bursitis can be a cause of acute or chronic anterior knee pain. It can affect the prepatellar, superficial infrapatellar, and/or deep infrapatellar bursae.

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Keywords/Tags: Anterior knee bursae, prepatellar bursa, infrapatellar bursae

8. EXPLANATION

A. Olecranon bursitis related to gout. Gout and rheumatoid arthritis are the most common system causes of olecranon bursitis. Systemic etiologies of olecranon bursitis should be suspected when the process is bilateral. Sonographically, olecranon bursitis typically presents as ill-defined subcutaneous edema/inflammation or a more focal inflammatory mass in the expected location of the olecranon bursa at the posterior elbow. Calcification of the involved bursa is more commonly seen with gout. Erosion of the adjacent olecranon can be seen with ultrasound as focal cortical irregularity of the normal expected smooth echogenic bone cortex (Figure 18.15).

Learning Points: Olecranon bursitis can be associated with gout, rheumatoid arthritis, injury, or infection. On ultrasound, it is seen as hypoechoic or heteroechoic fluid superficial to the olecranon process.

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Keywords/Tags: Olecranon bursitis, gout, rheumatoid arthritis

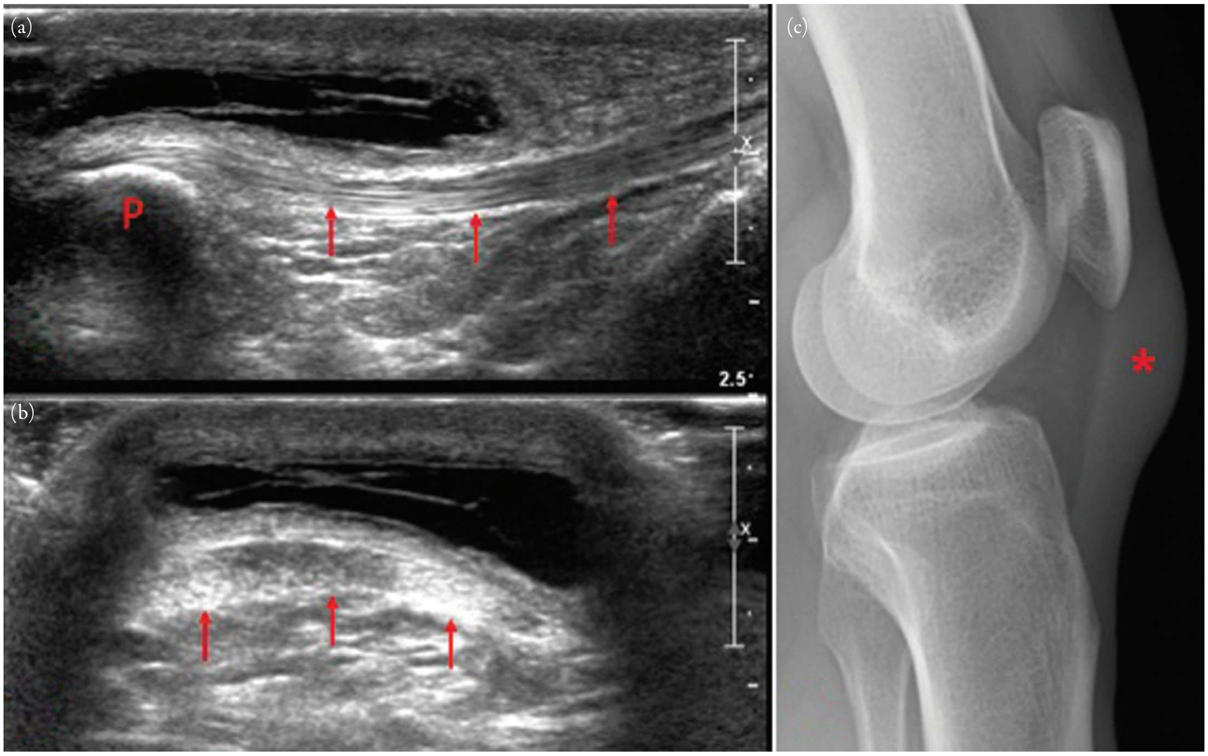

Figure 18.14 **Prepatellar bursitis.** Panels (a) and (b), respectively, show grayscale sonographic images in longitudinal and transverse plane of another patient with prepatellar bursitis. A septated cystic appearing soft tissue mass anterior to the proximal patellar tendon (arrows) extends from the inferior pole of the patella (P). Knee radiograph (Panel c) shows focal soft tissue prominence in the expected region of the prepatellar bursa (*).

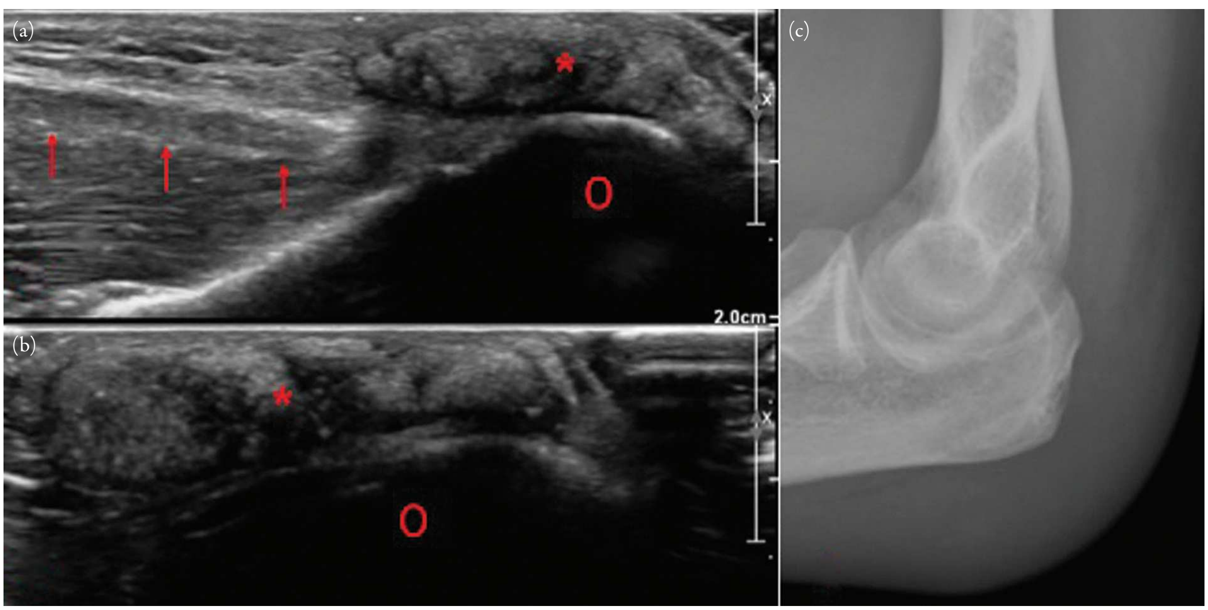

Figure 18.15 **Olecranon bursitis.** Panels (a) and (b) show grayscale sonographic images in longitudinal and transverse plane of the posterior elbow with a lobulated subcutaneous soft tissue mass in the region of the olecranon bursa. The mass (*) is located posterior to the distal triceps tendon (arrows) and posterior to the olecranon (O). Elbow radiographs (Panel (c)) show posterior elbow soft tissue swelling with a small posterior olecranon bone erosion.

9. EXPLANATION

B. Crystal deposition on the cartilage surface. Uric acid crystals in gout deposit on the surface of cartilage in a linear contiguous configuration. The parallel echogenic lines created by the gout crystal deposition and the adjacent echogenic subchondral bone is referred to as the double-contour sign. The crystals in calcium pyrophosphate dihydrate deposition (CPPD) disease deposit in a different pattern. The echogenic cartilage in this disease process deposit in the substance of the cartilage. The cartilage of the patellofemoral compartment is the thickest in the body and is a good location to search for findings of crystal deposition disease. The patellofemoral compartment cartilage of the knee is best evaluated from an anterior approach with the knee in maximum flexion (Figure 18.16).

Learning Points: Gout is associated with the double contour sign on ultrasound with monosodium urate crystal deposition along the surface of cartilage. Crystals in CPPD disease typically deposit within the cartilage.

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Keywords/Tags: Crystal deposition disease, CPPD disease, gout, trochlear cartilage

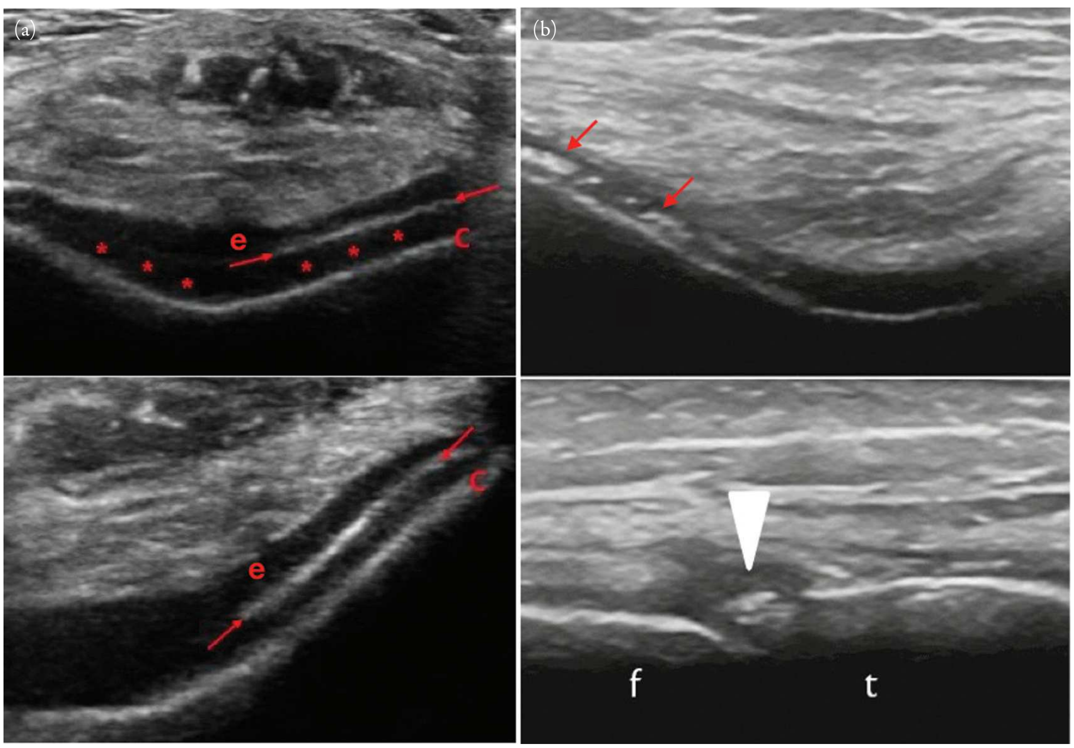

Figure 18.16 **(a) Uric acid deposition at the knee.** Top and bottom panels show grayscale sonographic images in transverse plane of the trochlear cartilage of the knee in a patient with a small hypoechoic knee joint effusion (e). The most posterior linear echogenic line on these images represents the trochlear bony cortex (C). Anterior to and paralleling the bone cortex is the thicker hypoechoic articular cartilage (*). Anterior to the articular cartilage is another linear echogenic region that represents the uric acid crystal deposition in gout (arrows). The 2 linear parallel echogenic lines represent the double contour sign of gout. **(b) Calcium pyrophosphate dihydrate (CPPD) deposition at the knee**. Top panel shows a grayscale transverse sonographic image of the trochlea with the echogenic CPPD crystals (arrows) deposited in the hypoechoic articular cartilage. Crystal deposition in CPPD occurs within the cartilage and not along the cartilage surface as seen with gout. Bottom panel shows the echogenic CPPD crystal deposition in the medial meniscus (arrowhead), between the femur (f) and tibia (t). Adapted from Figure 17.6 of Grassi W, Okano T, Filipucci E. Ultrasound in osteoarthritis and crystal-related arthropathies. In: Doherty M, Hunter DJ, Bijlsma H, Arden N, Dalbeth N, eds. *Oxford Textbook of Osteoarthritis and Crystal Arthropathy*. New York, NY: Oxford University Press; 2016:169–176.

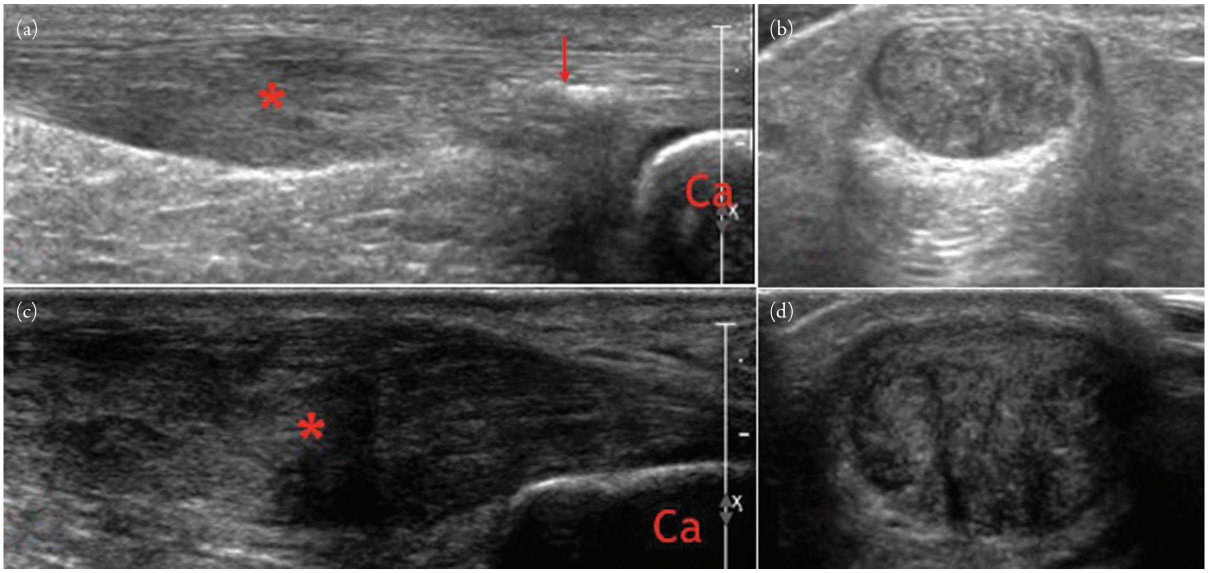

Figure 18.17 **Achilles tendinopathy.** Panels (a) and (b), respectively, show longitudinal and transverse ultrasound images of thickening and hypoechogenicity of the noninsertional segment of the Achilles tendon (*). Echogenic foci (arrow) with posterior acoustic shadowing in the Achilles tendon near the calcaneal (Ca) insertion represents dystrophic calcification. Panels (c) and (d), respectively, show images in longitudinal and transverse plane of a severely enlarged and hypoechoic Achilles tendon with loss of the normal fibrillar configuration of the tendon, which represents severe tendinopathy.

10. EXPLANATION

C. Chronic Achilles tendinopathy. The sonographic findings of tendinopathy include an enlarged and hypoechoic tendon with loss of the normal fibrillar tendon architecture. Tendinopathy can be isolated or associated with tenosynovitis or tendon tearing. Doppler signal can be increased in the abnormal tendon suggesting active inflammation. Tendon tears appear as focal defects in the tendon. Tears can be partial or complete (Figures 18.17, 18.18).

Learning Points: Tendinopathy on ultrasound manifests as an enlarged, hypoechoic tendon with loss of the normal fibrillar tendon configuration. Tendinopathy can be isolated or can be associated with tenosynovitis or tendon tears.

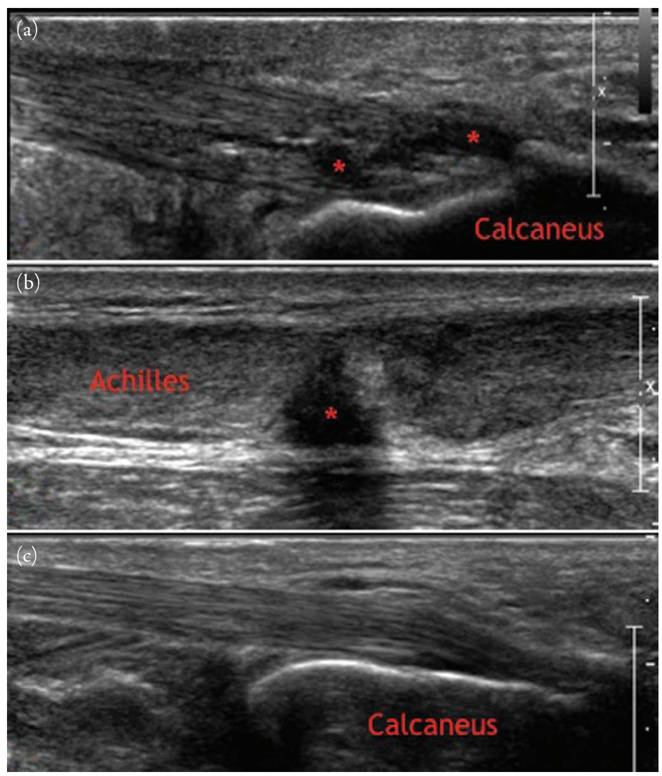

Figure 18.18 **Achilles tendon tear.** Panels (a) and (b), respectively, show longitudinal grayscale sonographic imaging of a patient with both insertional and noninsertional Achilles tendon tearing. Tendon tears appear as focal anechoic or hypoechoic defects (*) in the tendon. Panel (c) shows a longitudinal image of the normal contralateral Achilles tendon for comparison.

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Keywords/Tags: Tendinopathy

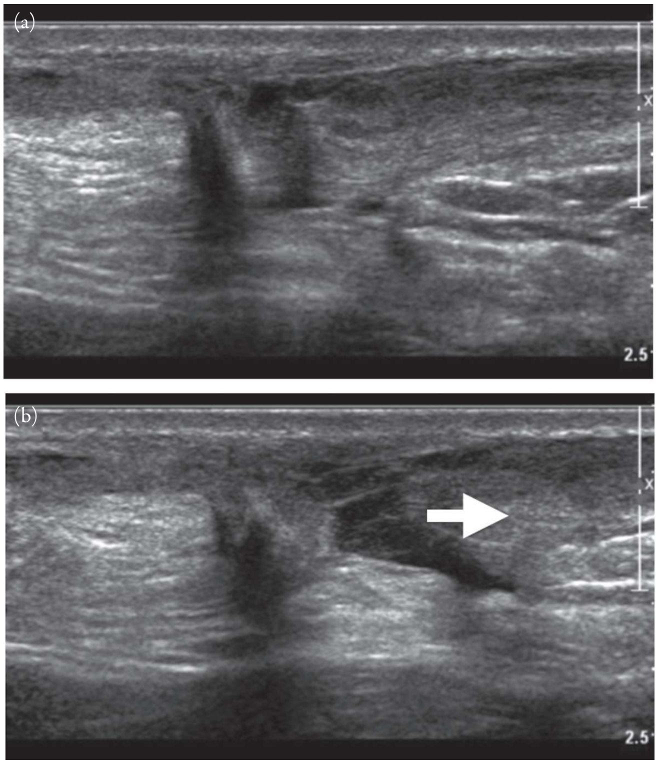

Figure 18.19 **Dynamic assessment of the Achilles tendon.** Panels (a) and (b), respectively, show longitudinal plane images of an Achilles tendon tear during plantar flexion and dorsiflexion to demonstrate the different position of the torn tendon segments between the 2 maneuvers. The gap between torn tendons is more conspicuous with dorsiflexion as the distal tendon (arrow) moves away from the proximal torn segment.

11. EXPLANATION

C. Use dynamic maneuvers with ultrasound imaging. Dynamic maneuvers during ultrasound imaging are very helpful in distinguishing partial from complete tears of the Achilles tendon. The ultrasound probe is placed over the region of suspected tearing in the longitudinal plane. Sonographic imaging is performed while the foot is dorsiflexed and plantar flexed. In patients with Achilles tendinopathy or partial tearing, the tendon moves as a unit during this dynamic maneuver. In complete tears of the Achilles tendon, the torn segments move in opposite direction with this maneuver. During dorsiflexion, the superior segment of the torn tendon moves proximally while the inferior segment of the torn tendon moves distally. The gap between torn tendons is made more conspicuous (Figure 18.19, Video 18.1).

Learning Points: Dynamic maneuvers are an important adjunct to evaluating Achilles tendon tears on ultrasound.

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Keywords/Tags: Achilles tendinopathy, Achilles tears, dynamic maneuvers

12. EXPLANATION

B. Finger tenosynovitis related to psoriatic arthritis (sausage digit). Tenosynovitis is nonspecific inflammation of the tendon sheath. Ultrasound images show a distended tendon sheath with material of varying echogenicity representing simple fluid, proteinaceous debris, or synovial hypertrophy from inflammatory arthritis or crystal deposition disease such as gout. The provided clinical history is typical for psoriatic arthritis. Increased color Doppler signal of the synovial hypertrophy can be a sign of active synovial inflammation (Figures 18.20, 18.21).

Recent studies have supported the reliability and prognostic value of point-of-care ultrasound (POCUS) in inflammatory arthritis. Filippou and colleagues in the STARTER study showed that evidence of active inflammation on color Doppler was associated with a 2- to 3-fold likelihood of rheumatoid arthritis flare at 12-month follow-up. In the international OMERACT study, Naredo et al. showed high inter-observer reliability of POCUS for identifying tenosynovitis severity in rheumatoid arthritis.

Learning Points: Tenosynovitis is inflammation of the tendon sheath. Ultrasound images show a distended tendon sheath with material of varying echogenicity.

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Keywords/Tags: Tenosynovitis, inflammatory arthritis, psoriatic arthritis

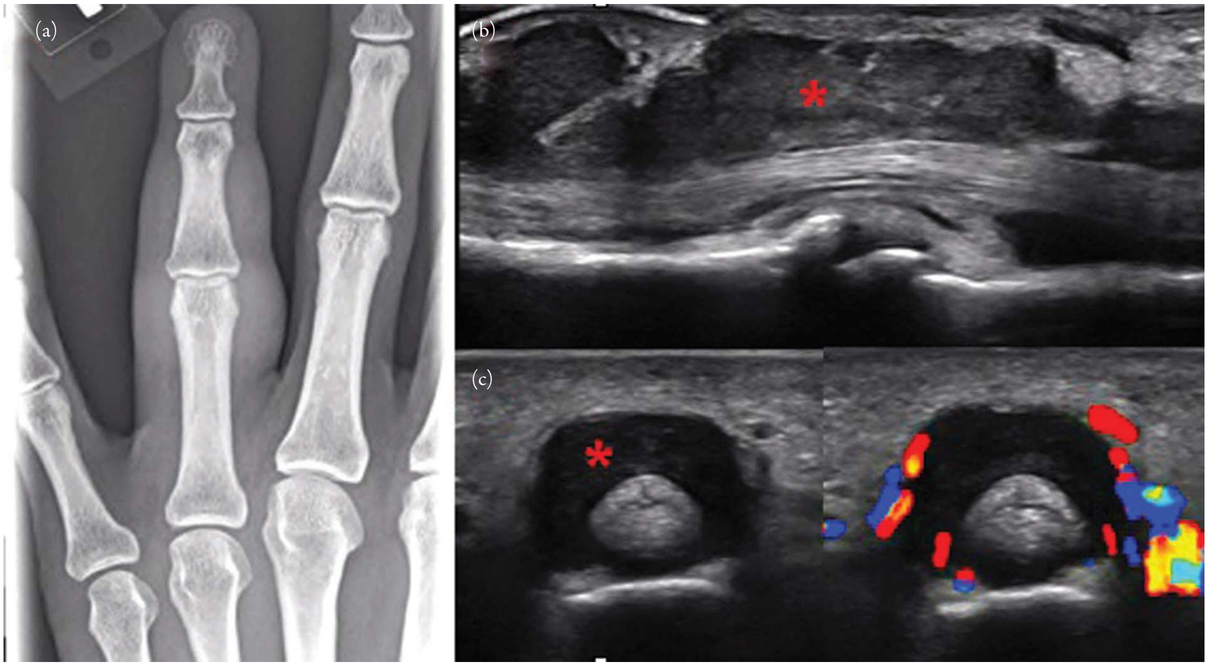

Figure 18.20 **Finger Tenosynovitis.** Panel (a) is a plain radiograph showing diffuse 4th finger soft tissue swelling. Panels (b) and (c), respectively, show long and short axis ultrasound images of the volar 4th finger at the proximal interphalangeal joint level with severe expansion of the flexor tendon sheath with echogenic material (*) consistent with a complex tenosynovitis. Panel (c) also shows a transverse color Doppler image with increased flow along the periphery of the tendon sheath suggesting hyperemia and possible active inflammation.

13. EXPLANATION

C. Inject into the biceps tendon sheath. Steroid and anesthetic injection for tenosynovitis of the long head of the biceps tendon is a common procedure. It should be noted that injecting steroids adjacent to partially torn tendon has been associated with progression of the tendon tear. As a general rule, steroids should not be injected into tendons due to the risk of tendon rupture. This holds true for injections in the treatment of tendinopathy and tenosynovitis throughout the body. The medicine is injected into the biceps tendon sheath surrounding the long head of the biceps tendon (Figures 18.22, 18.23).

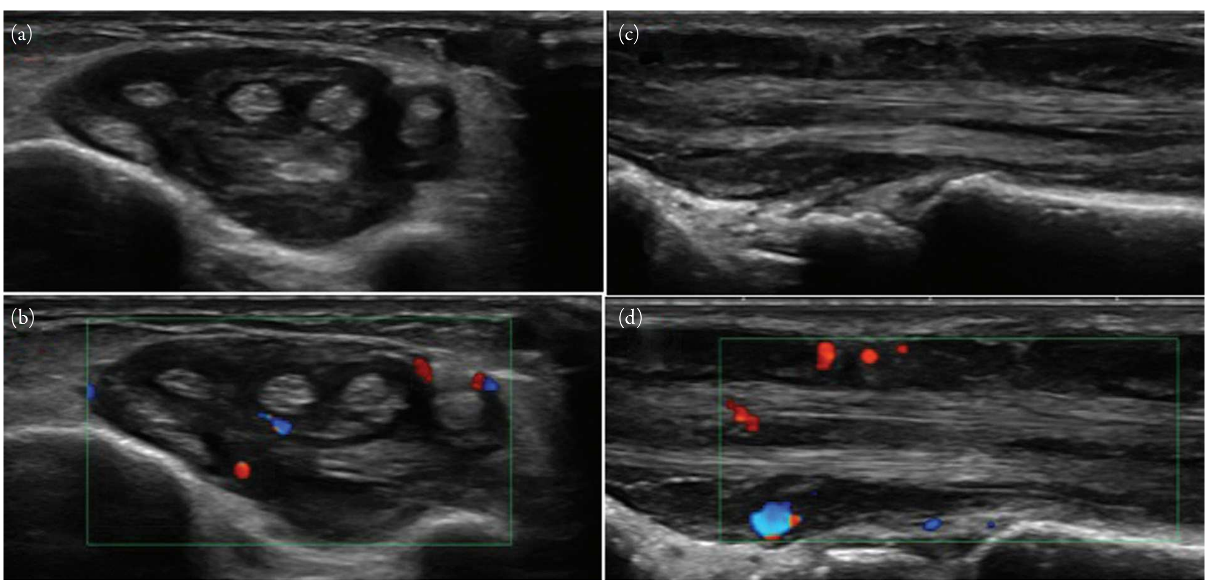

Figure 18.21 **Complex tenosynovitis of the wrist.** Panels (a) and (c), respectively, show grayscale sonographic imaging of the dorsal wrist in transverse and longitudinal planes with a complex tenosynovitis involving the fourth dorsal extensor compartment tendon sheath. The tendon sheath is expanded with solid-appearing echogenic material that has increased flow on color Doppler (Panels (b) and (d), respectively). The findings suggest synovitis with active inflammation.

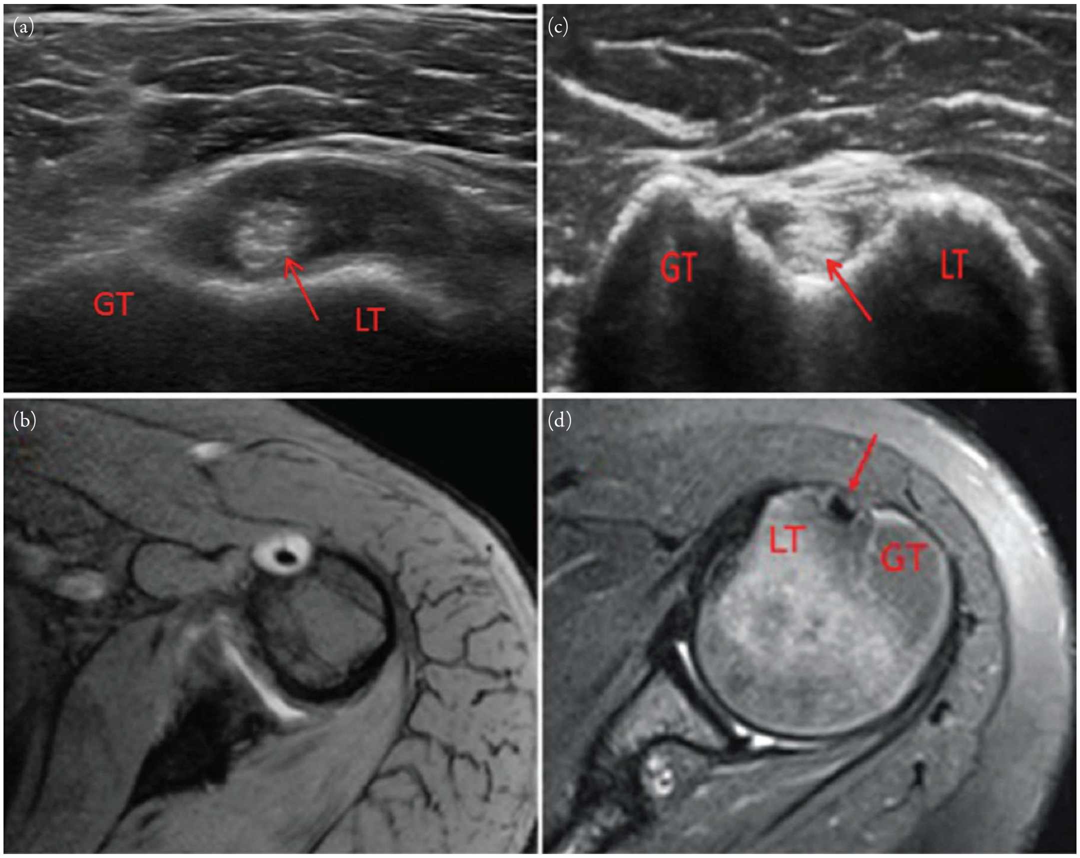

Figure 18.22 **Biceps tendon tenosynovitis.** Panel (a) is a grayscale sonographic image in transverse plane of the anterior shoulder showing expansion of the biceps tendon sheath compatible with biceps tenosynovitis in a patient with overlying anterior shoulder pain. The biceps tendon is the oval echogenic structure (arrow) in the intertubercular groove between the greater tuberosity (GT) and lesser tuberosity (LT). Corresponding axial fluid sensitive magnetic resonance image (MRI; Panel (b)) showing the hyperintense (bright) fluid signal surrounding the hypointense (black) biceps tendon in the intertubercular groove. Panel (c) shows a grayscale sonographic image in the transverse plane of the anterior shoulder in an asymptomatic patient with a normal biceps tendon. The biceps tendon sheath is not expaned. Axial fluid sensitive MRI sequence (Panel (d)) of a normal biceps tendon without increased fluid signal surrounding the tendon.

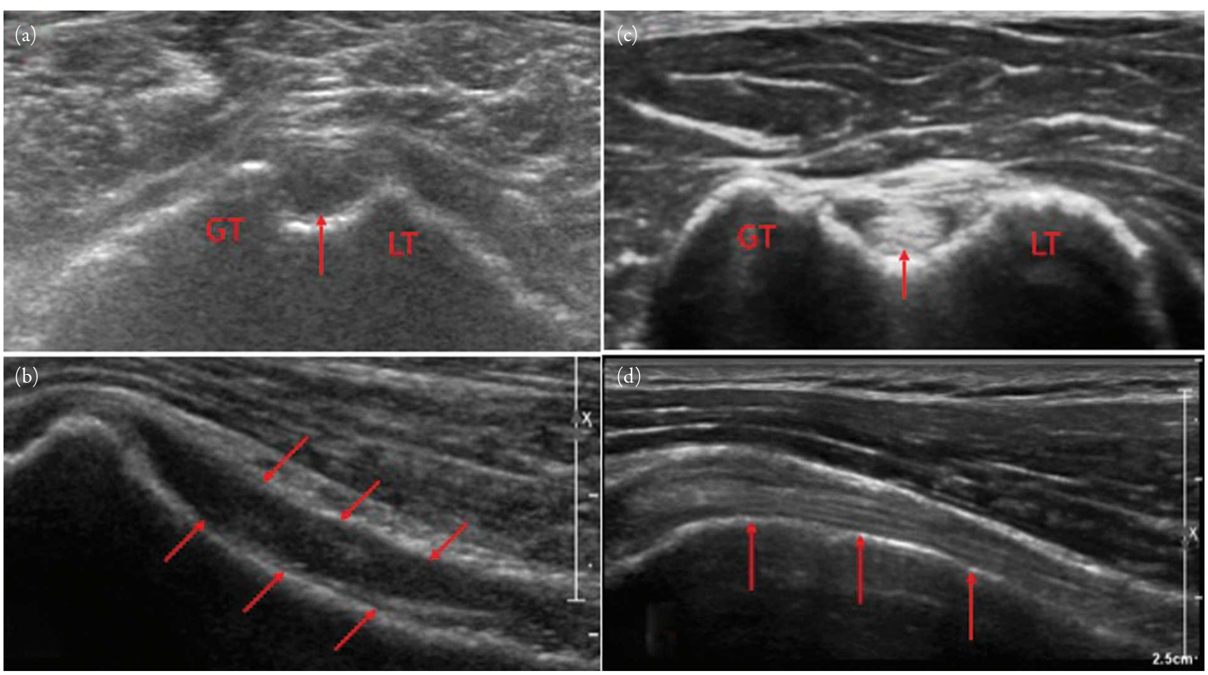

Figure 18.23 **Biceps tendon tear.** Panels (a) and (b), respectively, show grayscale sonographic images in transverse and longitudinal planes of the proximal anterior shoulder in the region of the intertubercular groove. The biceps tendon is completely torn and distally retracted and is not visible in the intertubercular groove (arrows). Panels (c) and (d), respectively, show a normal proximal long head of the biceps tendon in normal position in the intertubercular groove for comparison.

Learning Points: Tenosynovitis of the long head of the biceps tendon is a common cause of anterior shoulder pain. Ultrasound guided injection of the biceps tendon sheath is a treatment option.

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Keywords/Tags: Biceps tendon, tenosynovitis

14. EXPLANATION

A. Between the deltoid muscle and rotator cuff tendons. The SA-SD bursa is commonly inflamed in patients with external impingement. Ultrasound-guided injection of steroids and anesthetic into this bursa can provided pain relief in these patients. On ultrasound, the SA-SD bursa is found deep to the deltoid muscle and superficial to the rotator cuff tendons. In the absence of bursal inflammation, the SA-SD bursa is a potential space that is not clearly seen separate from the adjacent structures. Under ultrasound guidance, the needle tip is directed into the potential space between the deltoid muscle and rotator cuff tendons, and the injected medicine is seen distending the SA-SD bursa during the procedure (Figures 18.24, 18.25).

Learning Points: The SA-SD bursa is located between the deltoid muscle and rotator cuff tendons. This bursa can be inflamed in patients with external impingement. Ultrasound guided injection of the SA-SD bursa is a treatment option.

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Molini L, Mariacher S, Bianchic S. US guided corticosteroid injection into the subacromial-subdeltoid bursa: technique and approach. *J Ultrasound.* 2012;15:61–68.

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Keywords/Tags: Subacromial-subdeltoid bursa, external impingement

15. EXPLANATION

D. Calcific tendinosis with SA-SD bursitis. Calcific tendinosis affects primarily women in the 4th to 6th decades of life and may be associated with a history of shoulder overuse, such as in swimming. There are two phases: the more chronic resting or crystal formation phase and the resorptive phase. The former is associated with a milder, indolent pain, while the latter is associated with acute, severe, lancinating pain. The resorptive phase is self-limited to a few weeks and can be improved with steroid injection. The supraspinatus tendon is the most commonly affected rotator cuff tendon (Figures 18.26, 18.27).

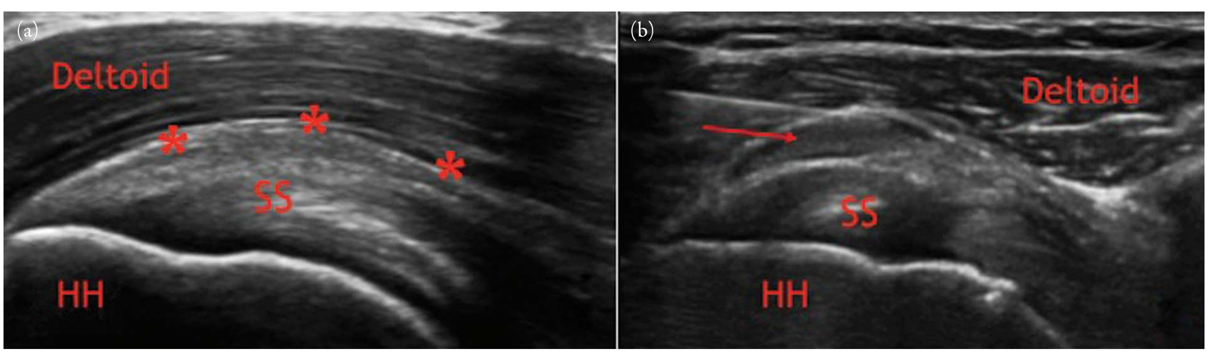

Figure 18.24 **Subacromial bursitis.** Panel (a) shows a grayscale sonographic image in longitudinal plane of the shoulder showing the expected location of the subacromial-subdeltoid (SA-SD) bursa. The SA-SD bursa (*) is a potential space deep to the deltoid muscle and superficial to the supraspinatous (SS) tendon on this image. The supraspinatous tendon is inserting on the humeral head (HH). In Panel (b), a grayscale longitudinal ultrasound images shows a linear hyperechoic needle tip (originating from the left) in the expected region of the SA-SD bursa during ultrasound guided bursa injection. The bursa (arrow) is distended prior to injection consistent with bursitis in this patient with signs and symptoms of external impingement.

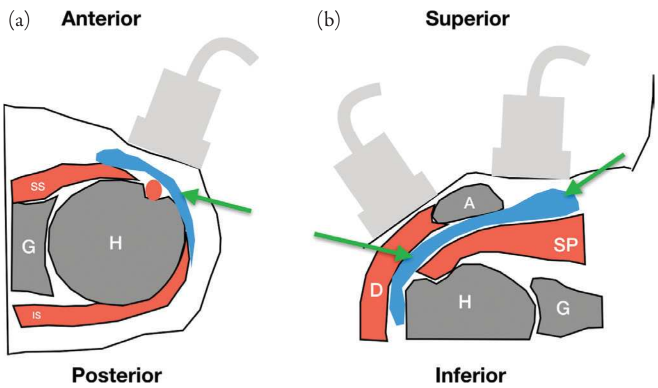

Figure 18.25 **Common subacromial-subdeltoid injection approaches.** In the anterior approach (a), the transducer is placed on the anterior shoulder and centered on the bicipital groove of the humeral head (H), and pointed posteriorly to obtain an axial plane. The needle is directed anterior-lateral to posterior-medial. In the superior or lateral approaches (b), the transducer is directed in a superior-inferior to obtain a coronal plane. In the superior approach, the transducer is placed just medial to the acromion (a). The needle is directed superior-medial to inferior-lateral. In the lateral approach, the transducer is placed lateral to the acromion. The needle is directed lateral to medial. G = glenoid rim. SS= subscapularis muscle. IS= infraspinatus muscle. D= deltoid muscle. SP= supraspinatus muscle.

Learning Points: Calcific tendinosis (hydroxyapatite deposition disease) can present as severe acute onset shoulder pain. On ultrasound, it is seen as irregular, calcified masses near the insertion point of tendons.

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Keywords/Tags: Calcific tendinosis, hydroxyapatite deposition disease

16. EXPLANATION

A. Anechoic with posterior acoustic enhancement. Simple cystic structures are typically homogeneously black or anechoic on ultrasound. Posterior acoustic enhancement is an important artifact that confirms the simple cystic nature of a mass. This artifact manifests as increased brightness or echogenicity posterior to the mass. There should also be no internal flow seen with color Doppler evaluation of simple cystic masses. Ganglion cysts, as in this case, are among the most commonly encountered soft tissue masses. These can arise from joints or tendon sheaths, but a direct connection is often difficult to identify (Figure 18.28).

Learning Points: Simple cystic soft tissues masses are anechoic and exhibit posterior acoustic enhancement.

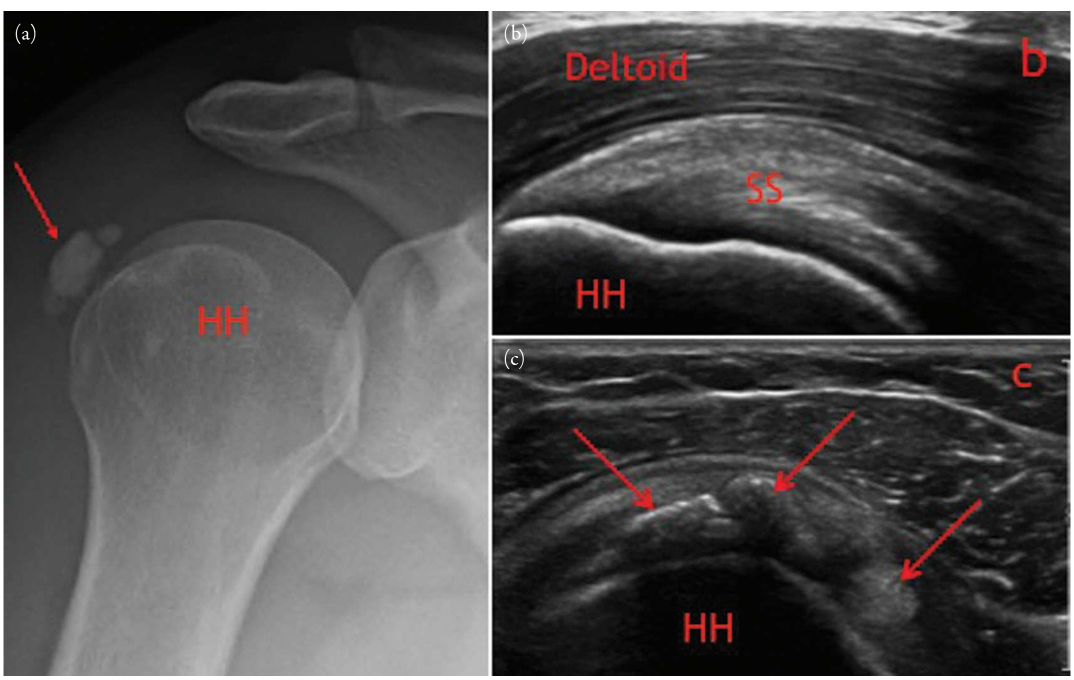

Figure 18.26 **Calcific tendinosis of the supraspinatus tendon.** Panel (a) shows an AP shoulder radiograph with smooth lobulated calcifications (arrow) projecting over the soft tissues near the lateral aspect of the humeral head. Panel (b) shows a grayscale sonographic image in longitudinal plane of the normal supraspinatous tendon (SS), while Panel (c) shows a grayscale longitudinal image of the supraspinatous tendon with echogenic calcific deposits (arrows).

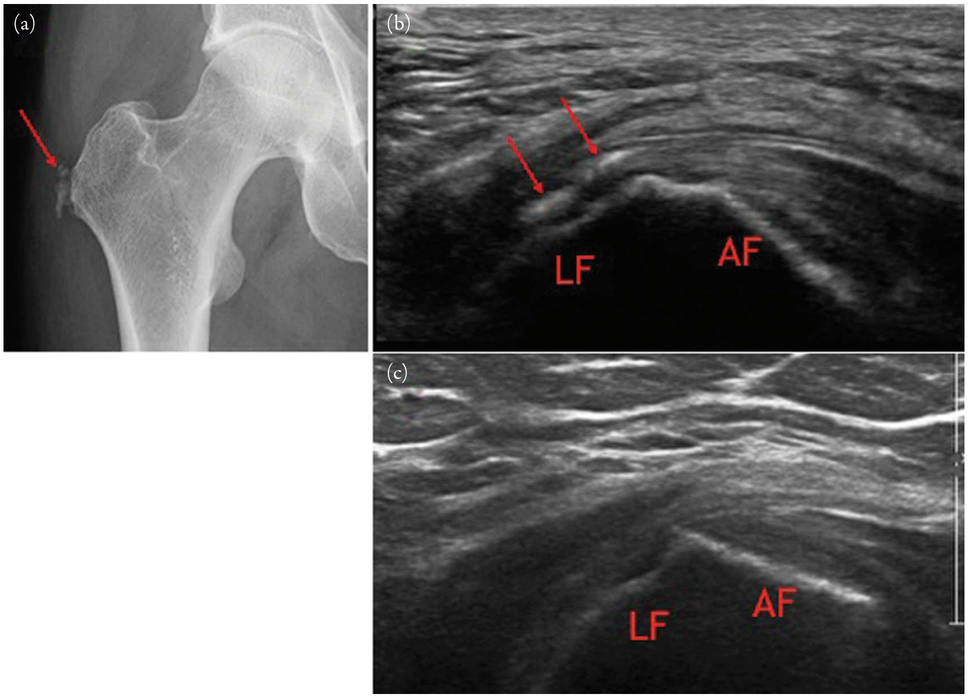

Figure 18.27 **Hip calcific tendinosis.** After the rotator cuff tendons of the shoulder, the second most common location for symptomatic hydroxyapatite deposition disease (HADD) is the gluteus tendon insertions at the greater trochanter. Irregular foci of calcification (arrow) project over the soft tissues near the right greater trochanter on this AP hip radiograph (Panel (a)). The transverse grayscale sonographic image (Panel (b)) of the lateral hip region shows 2 echogenic foci (arrows) near the lateral facet (LF) of the greater trochanter. This is the site of insertion of the gluteus medius tendon. The gluteus minimus tendon inserts on the anterior facet (AF). The transverse grayscale sonographic image (Panel (c)) of the asymptomatic contralateral greater trochanter in this patient shows no calcific deposits in the region of the greater trochanteric gluteus tendon insertions.

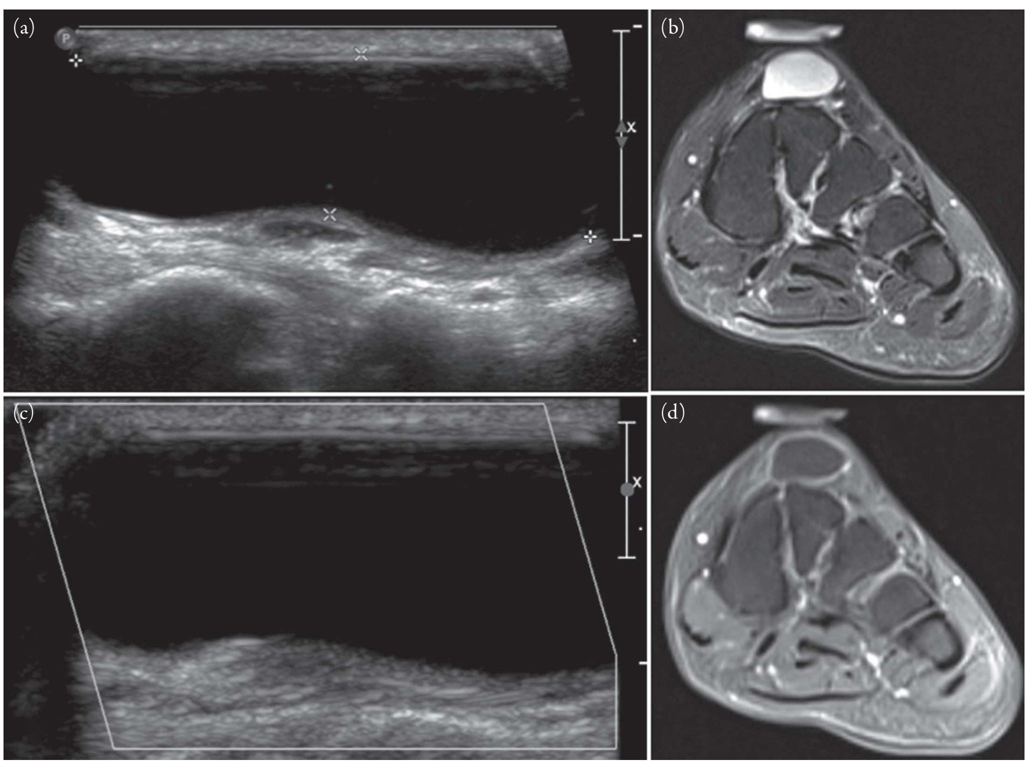

Figure 18.28 **Ganglion cyst of the foot.** Grayscale (Panel (a)) and color Doppler (Panel (b)) images in transverse plane of the dorsal mid-foot show a circumscribed anechoic subcutaneous soft tissue mass with posterior acoustic enhancement and no internal flow. Corresponding fluid sensitive (Panel (c)) and contrast-enhanced (Panel (d)) magnetic resonance images show a cystic dorsal mid foot mass that meets criteria for a simple cyst with only minimal peripheral enhancement.

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Keywords/Tags: Simple cyst, ganglion cyst, posterior acoustic enhancement

17. EXPLANATION

A. Irregular hypoechoic or echogenic mass without internal flow. Abscesses are seen in the context of suspected soft tissue infection. An irregular hypoechoic or echogenic mass without internal color Doppler flow is typical. The abscess may also have mobile internal debris and pockets of soft tissue gas that appear bright or echogenic on ultrasound. The so-called cobblestone appearance of the adjacent subcutaneous soft tissues can be seen with associated cellulitis (Figures 18.29, 18.30). Please note that any complex mass suspected to represent an abscess or hematoma, even without internal flow, should be followed clinically to resolution to exclude an underlying neoplasm. Answer choice C describes a solid mass with internal flow concerning for a neoplasm such as a soft tissue sarcoma. A circumscribed black or anechoic mass without internal flow is typical for a simple cystic structure like a ganglion. An oval hypoechoic mass with echogenic central hilum is typical for a lymph node.

Learning Points: On ultrasound, abscesses appear as irregular, anechoic, or hypoechoic cystic masses with central debris and no internal flow.

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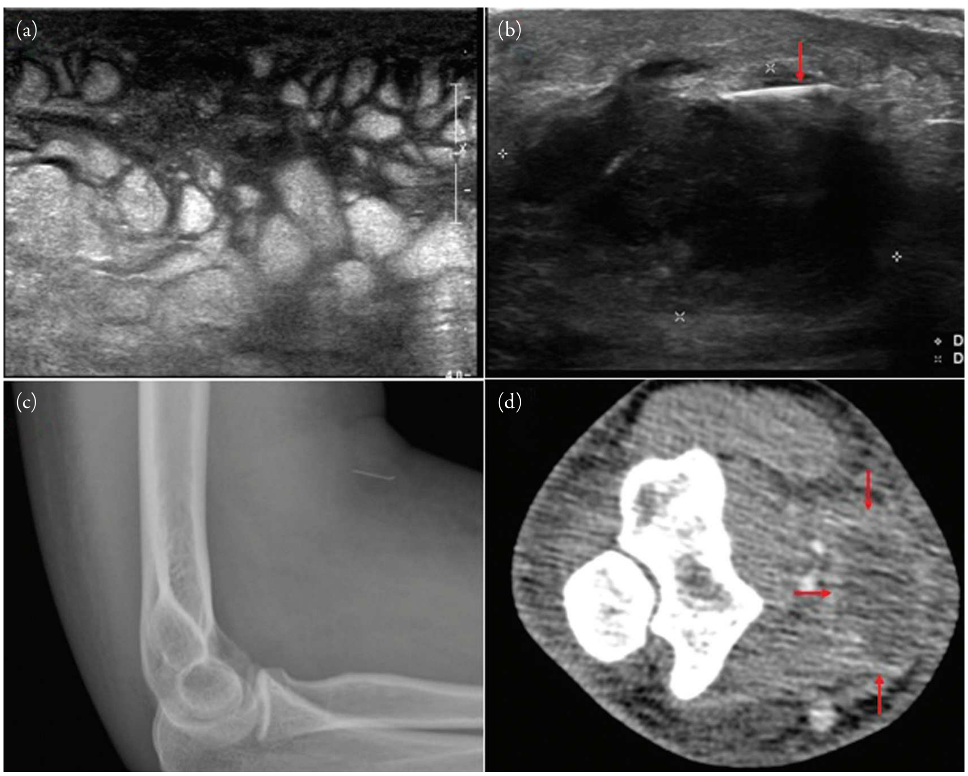

Figure 18.29 **Abscess of the antecubital fossa.** Panel (a) shows a grayscale ultrasound image of the proximal volar forearm in the transverse plane with ill-defined heterogeneous echogenicity of the subcutaneous soft tissues in a cobblestone pattern representing edema or inflammation. No focal drainable collection is seen. In Panel (b), a more well-defined hypoechoic soft tissue mass is seen proximal to the previously described edema. This abscess is adjacent to a retained linear foreign body (arrow). No flow is seen in the central portion of this mass with color Doppler (not shown). Panel (c) is an elbow radiograph showing the retained needle fragment. Panel (d) is an axial computed tomography image of the elbow after IV contrast showing a peripherally enhancing low-density structure (between arrows) corresponding to the presumed abscess seen on the ultrasound.

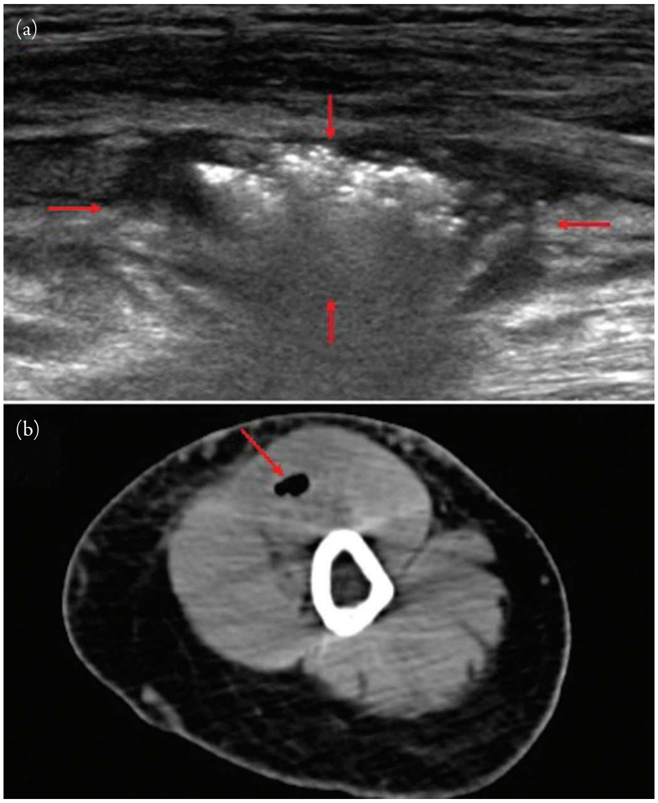

Figure 18.30 **Soft tissue gas in myonecrosis.** Panel (a) is a grayscale longitudinal sonographic image of the medial proximal arm showing an ill-defined region of heterogeneous echotexture (between the arrows). Numerous echogenic foci with so-called “dirty-shadowing” is the typical sonographic appearance of soft tissue gas. Panel (b) shows an axial computed tomography image of the arm shows the low density soft tissue gas (arrow) in the intramuscular phlegmon.

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Keywords/Tags: Abscess, complex cystic soft tissue mass

18. EXPLANATION

B. Low-grade lipomatous lesions like simple lipomas. Lipomas are the most commonly encountered soft tissues masses. Lipomatous (fat-containing) lesions range from simple benign lipomas, composed of mature adipocytes, to malignant liposarcoma. The clinical exam is critical in distinguishing benign from malignant soft tissue masses, including lipomatous lesions. Simple lipomas are typically soft, mobile, and compressible. Simple lipomas are typically nonpainful and very slowly enlarging masses. Any palpable soft tissue mass that is rapidly enlarging requires surgical referral for possible excisional biopsy.

Sonographically, most simple lipomas are located in the superficial subcutaneous soft tissues. Simple lipomas have a varied appearance and can be hypoechoic, isoechoic, or hyperechoic compared to adjacent subcutaneous fat. The borders of these lesions tend to be ill-defined and blend imperceptibly with subcutaneous fat. Simple lipomas do not typically have any internal Doppler signal (vascularity). The varied sonographic appearance of simple lipomas can cause confusion when imaging these masses. The key to making the correct diagnosis is to correlate the imaging findings with the physical examination (Figure 18.31, 18.32).

Learning Points: The most common benign soft tissue masses seen by ultrasound are lipomas and lymph nodes.

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Keywords/Tags: Soft tissue mass, lipomas

19. EXPLANATION

B. Solid heterogeneous mass with internal flow. Sonographic evaluation of largely solid soft tissue masses can be challenging. Most soft tissue masses are benign, including the commonly encountered lipomatous lesions (lipoma). Clinical evaluation is very important in the workup of these lesions. Any soft tissue mass that is rapidly enlarging is concerning for a soft tissue sarcoma. Relative large size and relative increased depth of a soft tissue mass on ultrasound should raise concern for a soft tissue sarcoma. Color Doppler evaluation of solid soft tissues masses can be deceiving. Most soft tissue sarcomas have some internal vascularity. Lack of color Doppler signal in a large heterogeneous soft tissue mass does not exclude a soft tissue sarcoma. Magnetic resonance imaging (MRI) can be performed to better characterize a concerning soft tissue mass (Figure 18.33).

Learning Points: Sarcomas appear as solid, heteroechoic masses on ultrasound, often with internal flow and/or calcifications.

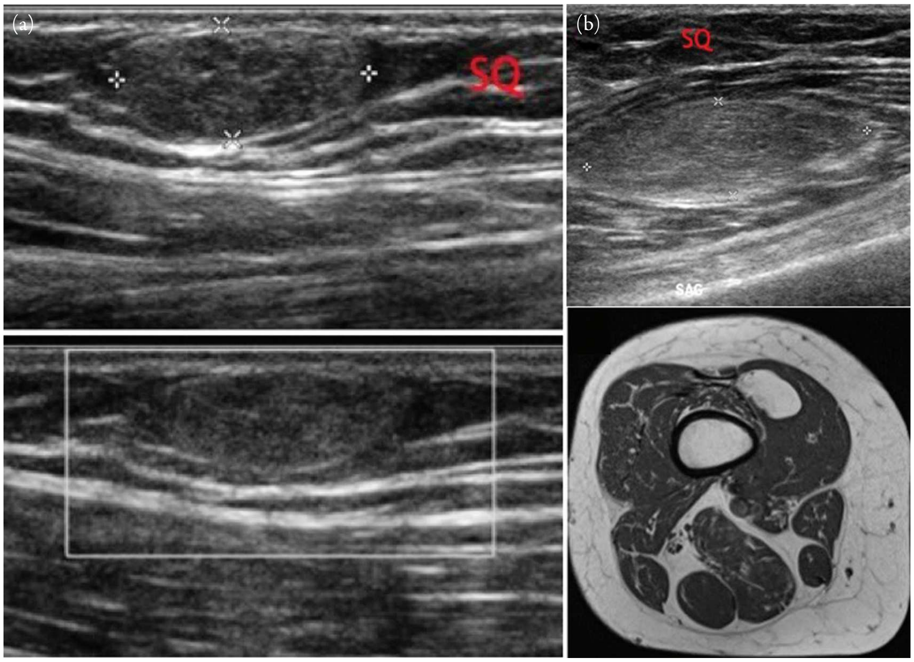

Figure 18.31 **(a) Subcutaneous lipoma**. Grayscale (top) and color Doppler sonographic images (bottom) in longitudinal plane of the volar forearm show a subcutaneous (SQ) soft tissue mass. The mass is hyperechoic compared to adjacent subcutaneous fat. Some of the lesion borders are not well seen and blend imperceptibly with the subcutaneous fat. No flow is seen on Doppler. **(b) Intramuscular lipoma**. Grayscale longitudinal ultrasound image of the thigh (top) shows an oval intramuscular soft tissue mass in the vastus medialis. The mass is heterogeneous in echotexture without internal flow on Doppler (not shown). This lipoma is not in the subcutaneous (SQ) soft tissues. Companion axial T1W magnetic resonance image (bottom) shows a circumscribed fat-signal intensity mass typical for a low-grade intramuscular lipomatous lesion such as a simple lipoma.

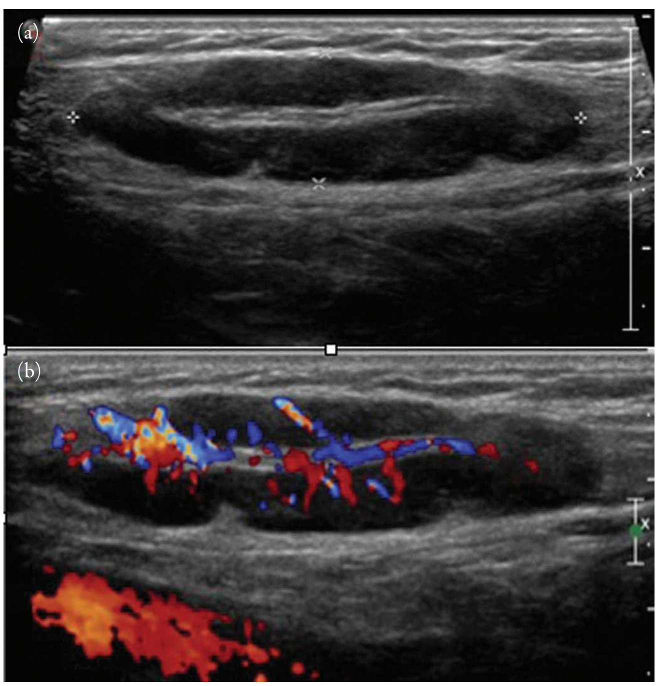

Figure 18.32 **Lymph node.** Grayscale and color Doppler sonographic images in longitudinal plane of the groin show a well-circumscribed subcutaneous soft tissue mass. The mass is mainly hypoechoic with a central vascular echogenic region. This is the typical sonographic appearance of a normal lymph node.

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Keywords/Tags: Soft tissue mass, sarcoma

20. EXPLANATION

D. Color and spectral Doppler evaluation of the mass. Doppler evaluation is a critical part of the evaluation of any soft tissue mass. This is especially true if intervention is planned to exclude a vascular lesion. Pseudoaneurysms are commonly encountered after trauma, including iatrogenic pseudoaneurysm formation after catheterization procedures. The characteristic "yin-yang" sign is seen with color Doppler imaging due to the turbulent forward and backward flow in these structures (Figure 18.34).

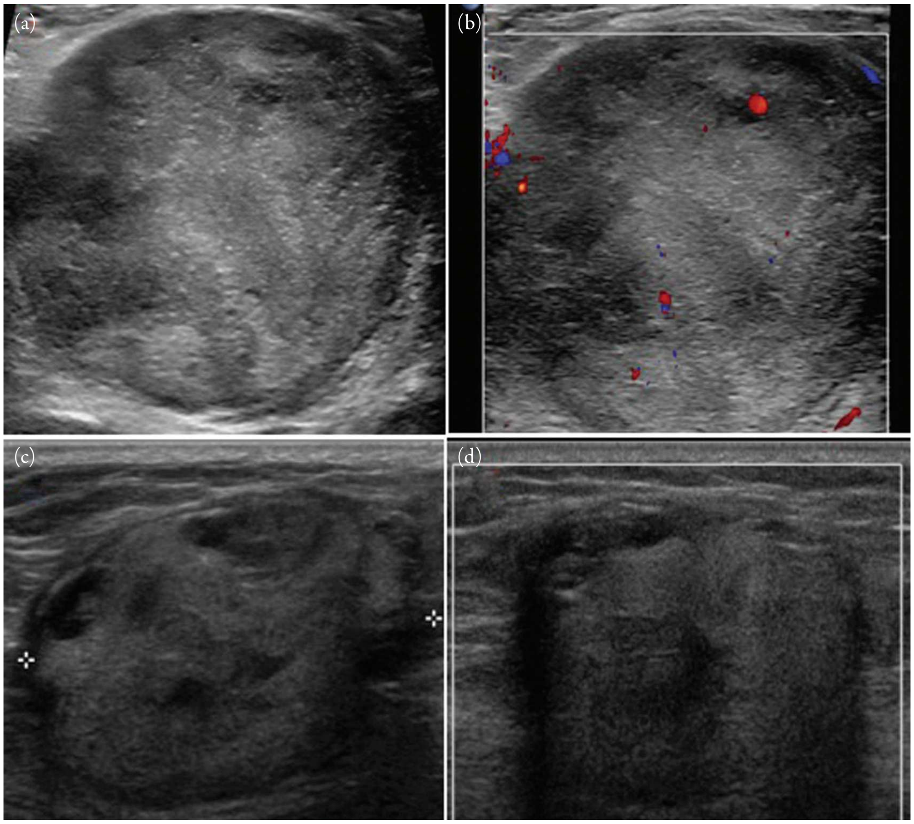

Figure 18.33 **Sarcoma on ultrasound.** Panels (a) and (b), respectively, show grayscale and color Doppler images in transverse plane of a solid-appearing soft tissue mass with heterogeneous echogenicity. The mass has internal flow on Doppler interrogation. A malignant soft tissue tumor must be excluded. Panels (c) and (d), respectively, show another soft tissue mass with heterogeneous echogenicity. There is no flow seen in this lesion with color Doppler. The absence of color Doppler signal in a solid appearing soft tissue mass does not exclude a malignant soft tissue mass. Both of these masses are biopsy proven soft tissue sarcomas.

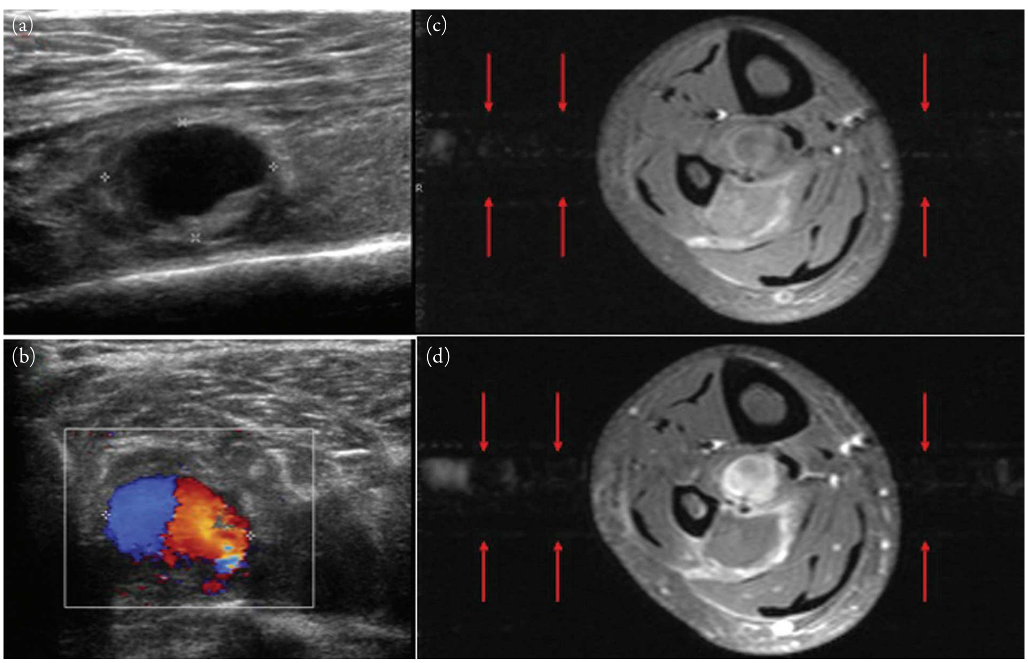

Figure 18.34 **Pseudoaneurysm.** Panel (a) shows a gray-scale sonographic image in transverse plane of a palpable intra-muscular mass in the leg. The mass is mainly anechoic with posterior acoustic enhancement. On color Doppler evaluation, the mass has significant internal flow with the typical "yingyang" appearance of a pseudoaneurysm (Panel (b)). Companion axial magnetic resonance (MR) images prior to (Panel (c)) and following IV contrast (Panel (d)) show a partially enhancing bi-lobed intramuscular soft tissue mass with MR pulsation artifact (arrows). Pulsation artifact is a helpful MR imaging artifact used to confirm that the mass is vascular.

Ultrasound-guided thrombin injection is a treatment option for certain pseudoaneurysms.

Learning Points: Pseudoaneurysms will exhibit the "yin-yang" sign on color Doppler, indicating to-and-fro flow.

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Keywords/Tags: Vascular lesions, pseudoaneurysm

Learning Points: Densely calcified masses exhibit shadowing artifact and are thus inadequately visualized on ultrasound.

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DiDomenico P, Middleton W. Sonographic evaluation of palpable superficial masses. *Radiol Clin North Am*. 2014;52(6):1295–1305.

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Keywords/Tags: Calcified soft tissue mass

21. EXPLANATION

B. Plain radiograph of the arm. The extensive posterior acoustic shadowing associated with this arm mass is most likely related to calcifications. A plain radiograph will clearly demonstrate these calcifications. Calcifications in a soft tissue mass are nonspecific and can be from benign causes such as prior hemorrhage. Calcification is also associated with some malignant soft tissue masses like synovial sarcoma. This case highlights the limitations of ultrasound in the region of dense structures such as calcium, bone, or metal. Do not hesitate to order a plain radiograph to further evaluate findings seen on ultrasound (Figure 18.35).

22. EXPLANATION

B. Enlarged and hypoechoic just proximal to the site of impingement. The median nerve is typically enlarged and hypoechoic just proximal to the site of impingement and flattened distal to the site of impingement. The enlarged appearance of the nerve is typically seen proximal to the carpal tunnel or in the proximal carpal tunnel at the level of the scaphoid and pisiform bones. A flattened nerve can be seen in the distal carpal tunnel at the level of the hook of the hamate. The upper limit of normal for the cross-sectional area of the median nerve is 9 to 12 mm^2 (Figures 18.36, 18.37).

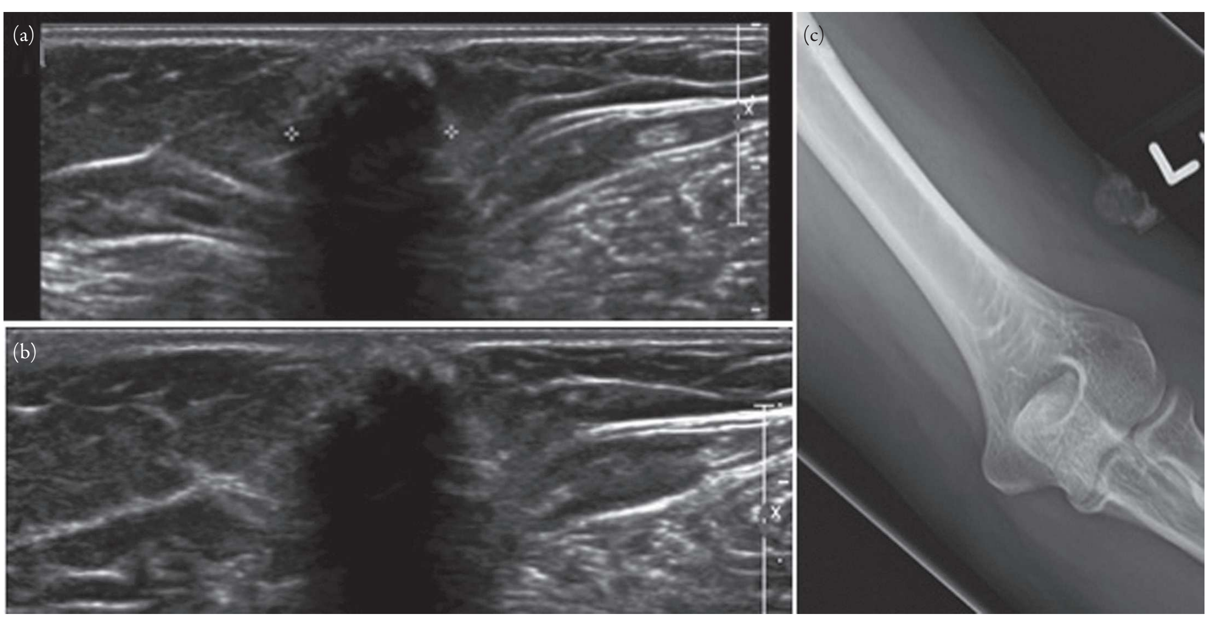

Figure 18.35 **Soft tissue calcified mass.** Panels (a) and (b), respectively, show grayscale sonographic images in longitudinal plane of a heavily calcified solid soft tissue mass with extensive posterior acoustic shadowing. A companion plain radiograph demonstrates a partially calcified soft tissue mass (Panel (c)).

Figure 18.36 **Technique for identifying the median nerve.** Place the transducer in transverse plane about 5 cm proximal to the wrist joint to identify the honeycomb-shaped median nerve (arrow), which rests between the flexor digitorum muscle bellies. The probe can be moved distally to follow the median nerve into the carpal tunnel.

Learning Points: The typical appearance of the median nerve in carpal tunnel syndrome is that of an enlarged and hypoechoic nerve proximal to site of impingement and a flattened nerve distal to the site of impingement.

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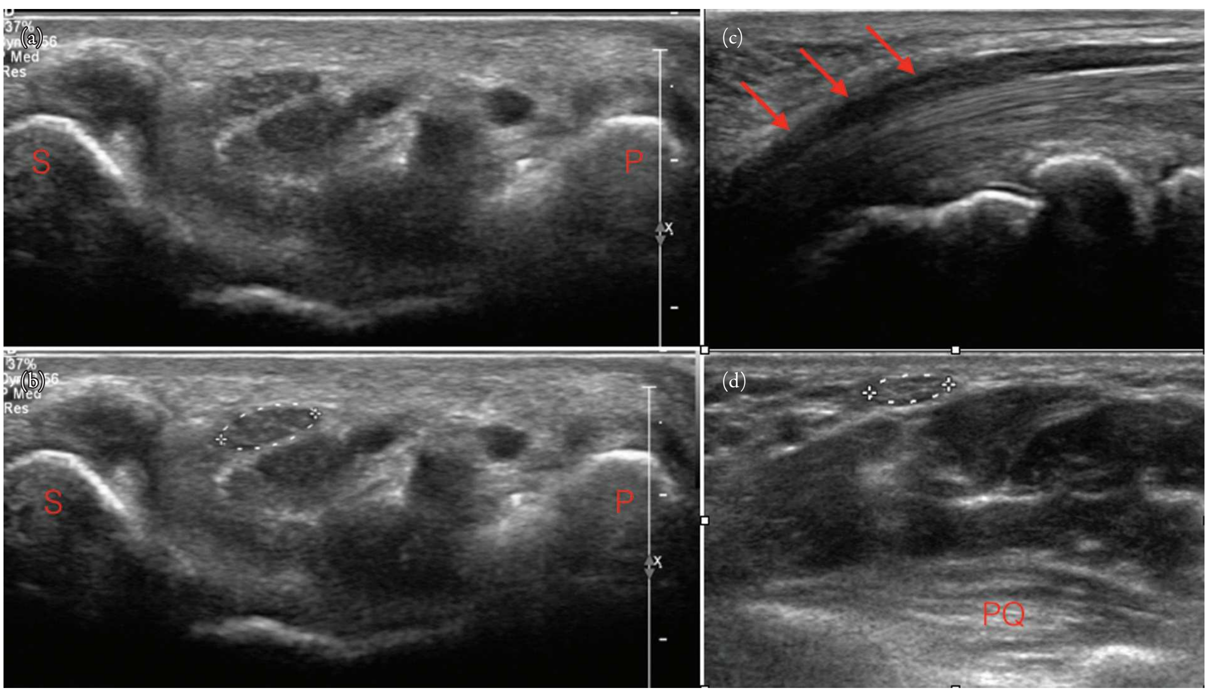

Figure 18.37 **Median nerve on ultrasound.** Panels (a) and (b), respectively, show grayscale sonographic images in transverse plane of the median nerve at the level of the proximal carpal tunnel without and with calipers outlining the nerve. The medial nerve appears as an oval structure in the superficial aspect of the carpal tunnel. The proximal carpal tunnel is identified by the bony landmarks of the scaphoid (S) on the radial side and the pisiform (P) on the ulnar side. The median nerve in these images has the typical honeycomb appearance of all nerves on ultrasound. Panel (c) is a sonographic image in longitudinal plane of the median nerve in the carpal tunnel. The nerve (arrows) is more hypoechoic than the underlying flexor tendons. Panel (d) is a transverse image of the volar wrist proximal to the carpal tunnel at the level of the pronator quadrates (PQ) muscle. The cross-sectional area of the median nerve is being measured with calipers at this level. The area of the median nerve at this level is expected to be less than the area of the enlarged nerve closer to the site of impingement more distally in the carpal tunnel region. A difference of >2 mm^2 cross-sectional area of the median nerve measured at the level of the pronator quadratus and at the level of the proximal carpal tunnel is indicative of median neuropathy.

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Keywords/Tags: Carpal tunnel syndrome, median nerve

23. EXPLANATION

B. Wood and plastic. Wood, including plant material, and plastic are difficult to seen on plain radiographs. These materials are seen well on ultrasound. Most foreign bodies appear echogenic on ultrasound. Artifact associated with foreign bodies can help in identification. Posterior acoustic shadowing and reverberation artifact are the most commonly seen artifacts associated with foreign bodies on ultrasound (Figure 18.38).

Learning Points: Ultrasound can identify non-radiopaque foreign bodies such as wood or plastic. Radiopaque foreign bodies such as glass and metal can also be seen by ultrasound.

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Keywords/Tags: Foreign bodies

24. EXPLANATION

C. Hypoechoic thickened plantar fascia (>4 mm). Plantar fasciitis is a common cause of heel pain. The plantar fascia origin is thickened (>4 mm) and hypoechoic in cases of plantar fasciitis. Identifying the echogenic cortex of the posterior

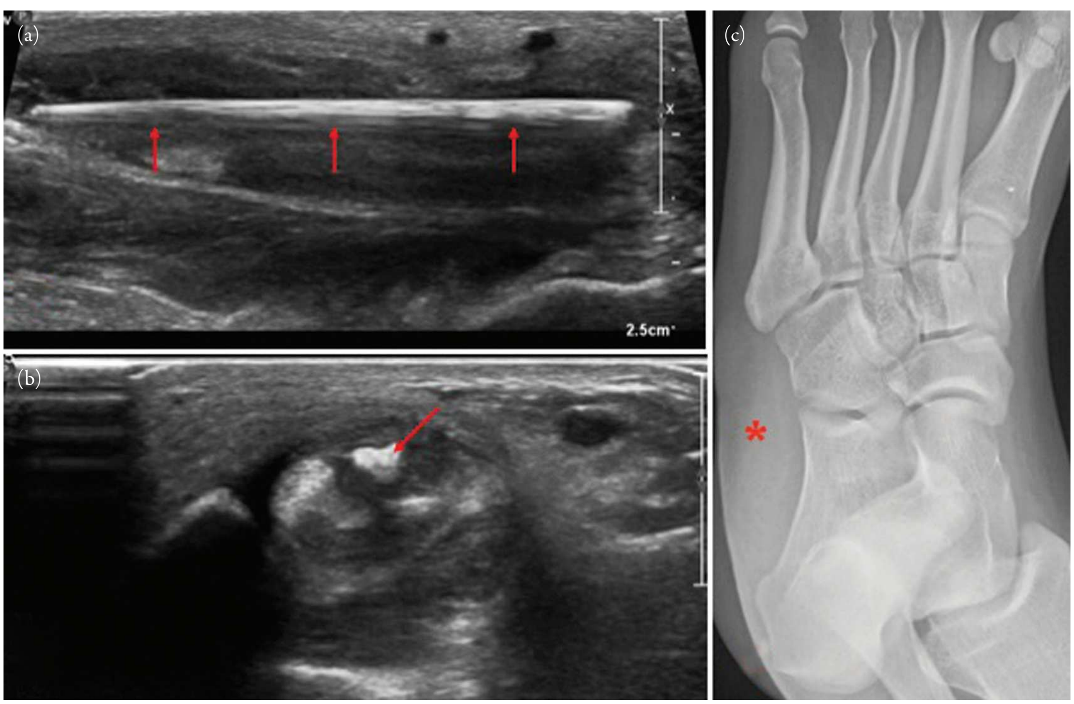

Figure 18.38 **Missed wood splinter foreign body in sole.** Panels (a) and (b), respectively, show grayscale sonographic images in longitudinal and transverse plane of the plantar lateral hind foot with a 5 cm linear echogenic foreign body (arrows) in the common peroneal tendon sheath. The common peroneal tendon sheath is expanded with hypoechoic debris consistent with a complex chronic tenosynovitis in this patient with a retained wood splinter for 5 months. There is no radiopaque foreign body seen in the expected location (*) of the wood splinter on the foot radiograph (Panel (c)).

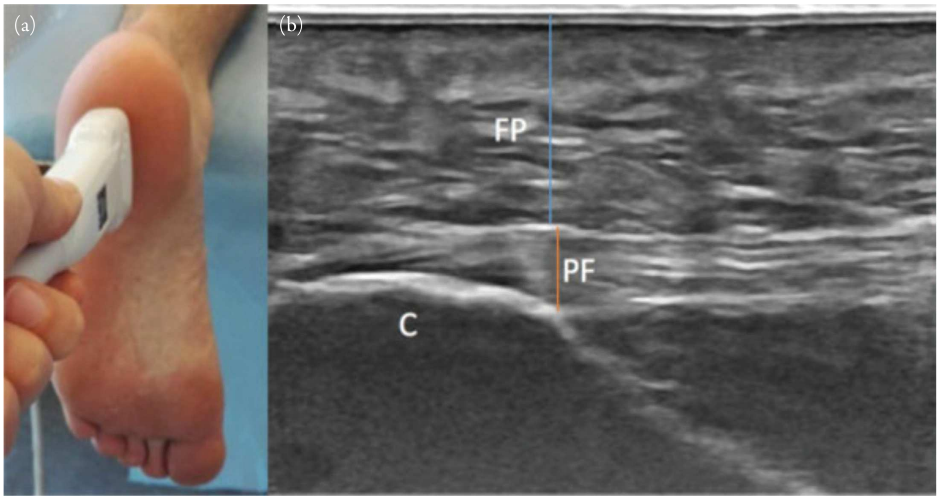

Figure 18.39 **Ultrasound of normal plantar fascia.** The transducer is placed in a longitudinal plane from heel to toes (Panel (a)). On ultrasound (Panel (b)), the calcaneus (C) is identified, along with the superficial fat pad (FP) and the plantar fasia (PF). Notice that the plantar fascia is normally ≤4 mm and hyperechoic in relation to the fat pad. From Figure 1 of Hansen L, Krogh TP, Ellingsen T, Bolvig L, Fredberg U. Long-term prognosis of plantar fasciitis: a 5- to 15-year follow-up study of 174 patients with ultrasound examination. *Orthop J Sports Med*. 2018;6(3):2325967118757983.

inferior calcaneus is the key to finding the proximal plantar fascia with ultrasound. Ultrasound-guided plantar fascia injection is used in the treatment of this disease. Steroids and anesthetic are injected in close proximity to the plantar fascia origin. Injection of steroids into the heel fat pad is discouraged as this can result in fat pad atrophy, which can exacerbate the patient's symptoms. The prognosis of plantar fasciitis can be poor, as up to 50% of patients will continue to have recurrent flares, with risk factors of a poor prognosis including female sex, bilateral heel pain, and presence of autoimmune disease (Figures 18.39, 18.40).

Learning Points: Plantar fasciitis is a common cause of heel pain. Ultrasound typically shows a thickened and hypoechoic proximal plantar fascia in patients with plantar fasciitis.

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Keywords/Tags: Plantar fasciitis

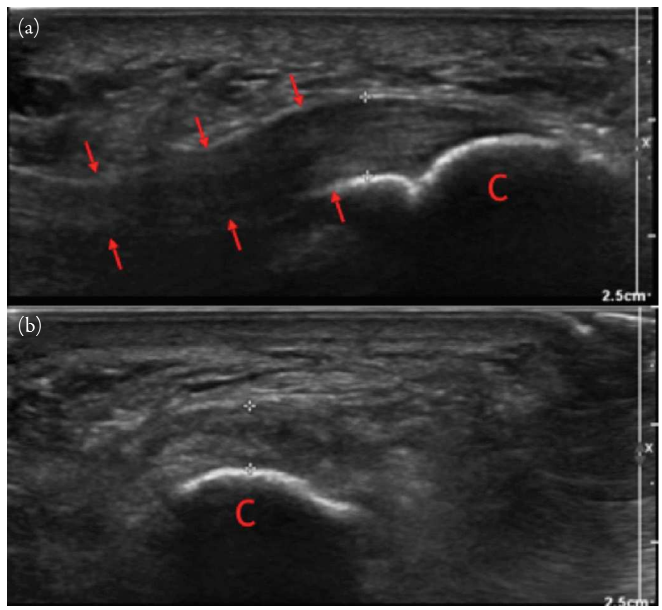

Figure 18.40 **Plantar fasciitis on ultrasound.** Grayscale sonographic images in longitudinal (a) and transverse (a) plane of the proximal plantar fascia near its calcaneal origin in the proximal plantar aspect of the hindfoot. Thickening and hypoechogenicity of the plantar fascia noted. The key anatomic landmark of the calcaneus (C) is shown.

25. EXPLANATION

B. Trigger finger, thickening of the A1 pulley. Trigger finger results from repetitive injury to one of the pulleys along the flexor side of the fingers. The pulleys are focal thickenings of the flexor tendon sheath that serve to keep the flexor tendons opposed to the bone finger during flexion of the finger. A1 to A5 pulleys present in each finger. The A1 pulley is most commonly involved at the metacarpophalangeal joint

level with the trigger finger phenomenon. The classic clinical scenario is a finger that gets locked in flexion and then with a painful snapping sensation goes into extension. The normal pulley is very thin and difficult to seen on ultrasound. Pathologic thickening of a pulley makes this structure more conspicuous on ultrasound (Figures 18.41, 18.42).

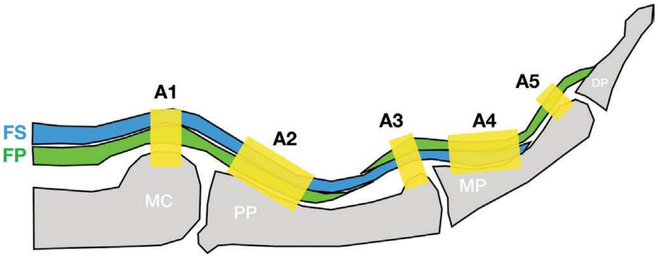

Figure 18.41 **Digital flexor system.** This is a schematic of the digital flexor anatomy on lateral view. The digital annular pulleys stabilize both the flexor digitorum profundus and superficialis tendons (FP and FS, respectively), as they travel from the metacarpal bone (MC), to proximal, mid, and distal phalanges (PP, MP, DP, respectively). The A1 pulley is located at the metacarpal-phalangeal (MCP) joint and is most commonly affected by trigger finger.

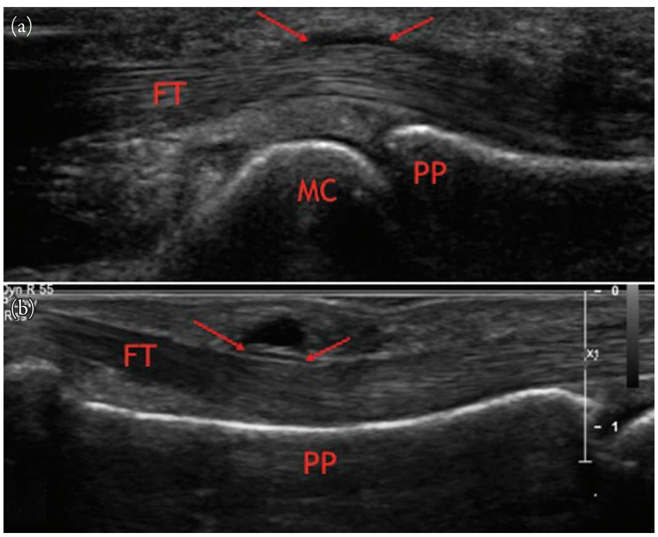

Figure 18.42 **Trigger finger on ultrasound.** Grayscale sonographic image (a) of the flexor aspect of the finger in longitudinal plane at the level of the metacarpophalangeal joint (MC = metacarpal head and PP = proximal phalanx). Thickened A1 pulley (between arrows) appears as a linear hypoechoic structure at the level of the metacarpal head (MC) immediately superficial to the flexor tendons (FT). The normal pulley is a thin linear almost imperceptible hypoechoic structure immediately superficial to the flexor tendons. Grayscale longitudinal image (b) of a minimally thickened A2 pulley (between arrows) at the mid-proximal phalanx (PP) level. A small hypoechoic structure is associated with this A2 pulley. This is a simple cyst.

Learning Points: Trigger finger results from repetitive injury to one of the pulleys along the flexor side of the fingers. The A1 pulley is most commonly involved at the metacarpophalangeal joint level with the trigger finger phenomenon.

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Keywords/Tags: Trigger finger, pulley lesion

26. EXPLANATION

A. Focal disruption or discontinuity of the echogenic bone cortex. Ultrasound is increasingly being used in the emergency setting as an adjunct to plain radiographs in extremity fracture detection. Ultrasound avoids the use of ionizing radiation in susceptible patient populations such as children and pregnant patients. Sonographically, long bone fractures are diagnosed when a focal break, disruption, or discontinuity of the smooth linear echogenic bone cortex is identified (Figure 18.43). The

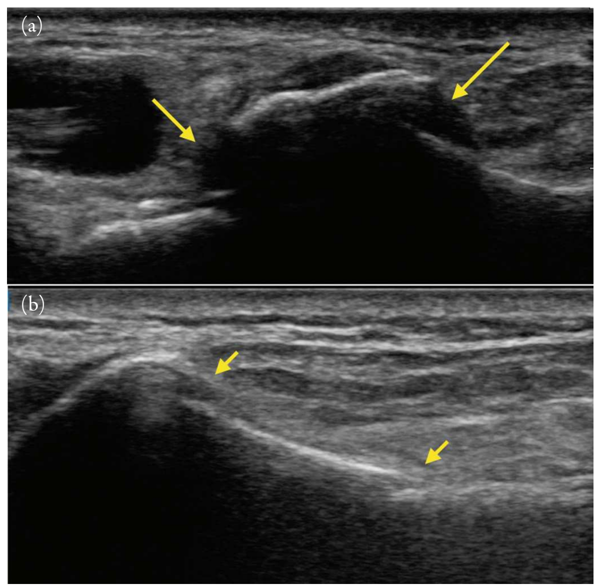

Figure 18.43 (a) **Comminuted distal radius fracture on ultrasound.** A longitudinal grayscale sonographic image of the distal forearm shows focal disruption of the linear echogenic bone cortex of the distal radius (arrows). Note the smooth normal linear echogenic bone cortex of the radius proximal and distal to the fracture site. (b) **Fracture after reduction on ultrasound.** During a reduction procedure, it is often difficult to assess successful reduction given surrounding tissue edema. The use of point-of-care ultrasound can allow the clinician to visualize the relative distance between fractured segments. Once adequate reduction is achieved, sedation can be discontinued, the fracture splinted, and confirmatory radiographs can be obtained.

presence of a soft tissue hematoma (described in answer choice B) or a posttraumatic pseudoaneurysm (described in answer choice D) can occur with or without a fracture.

Learning Points: Ultrasound is a useful adjunct to plain radiography in extremity fracture diagnosis. It can also be used to assess fracture reduction success periprocedurally, prior to confirmation with radiographs.

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Keywords/Tags: Fracture

27. EXPLANATION

C. Anterior humeral head dislocation. Sonographic evaluation of the glenohumeral joint is best performed from the posterior aspect of the shoulder with the ultrasound probe placed parallel to the scapular spine. A curvilinear low frequency (5–2 MHz) transducer is often required to adequately visualize the glenohumeral joint, which is positioned deeper than the rotator cuff tendons or the biceps tendon. In anterior dislocation, the humeral head is displaced away from the transducer and located deeper on the sonographic image compared to the normal joint. In posterior dislocation, the humeral head is closer to the ultrasound probe and is more superficial on the ultrasound image compared to the anatomic shoulder (Figure 18.44).

Learning Points: Ultrasound is an excellent tool in both the accurate diagnosis of glenohumeral joint dislocation and in the confirmation of normal joint alignment postreduction.

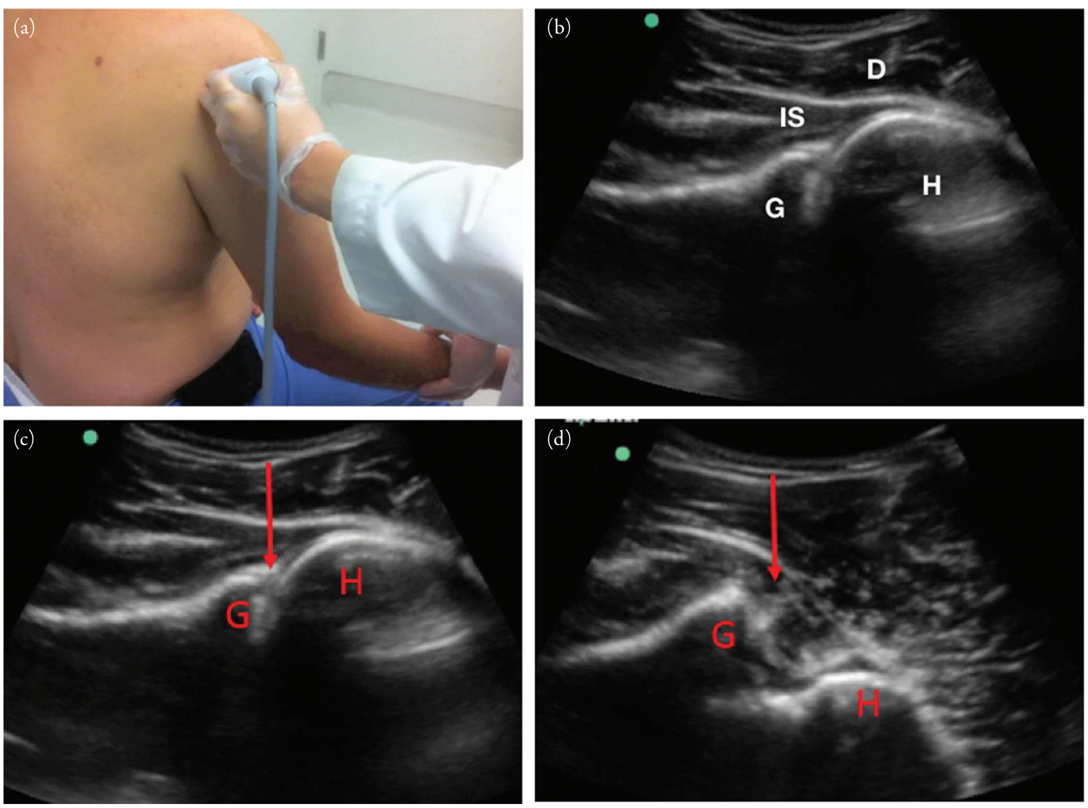

Figure 18.44 **Posterior shoulder ultrasound.** Images of ultrasound probe position (a) and the corresponding transverse grayscale ultrasound image (b) of the posterior shoulder. The transducer is positioned in a transverse position just inferior to the scapular spine. In this posterior image of the shoulder (b) the structures closest to the probe, at the superior aspect of the image, are located more posteriorly in the body. The structures farthest from the probe, at the inferior aspect of the sonographic image, are located more anteriorly in the body. The deltoid muscle (D) is seen superficially, with the infraspinatus muscle and tendon (IS) just deep to it. The IS attaches to the greater tuberosity of the humeral head (H). It can be seen contracting with external rotation of the shoulder. The gleno-humeral joint is formed by the humeral head and the glenoid rim (G). In a normal shoulder (c), the posterior cortex of the humeral head is more posterior (arrow) than the glenoid. In an anterior shoulder dislocation (d), the humeral head (H) is displaced anteriorly (arrow) compared to the glenoid (G). This places the humeral head (H) farther from the probe and more inferior on the sonographic image compared to the normal shoulder (c).

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Keywords/Tags: Glenohumeral joint, shoulder dislocation

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